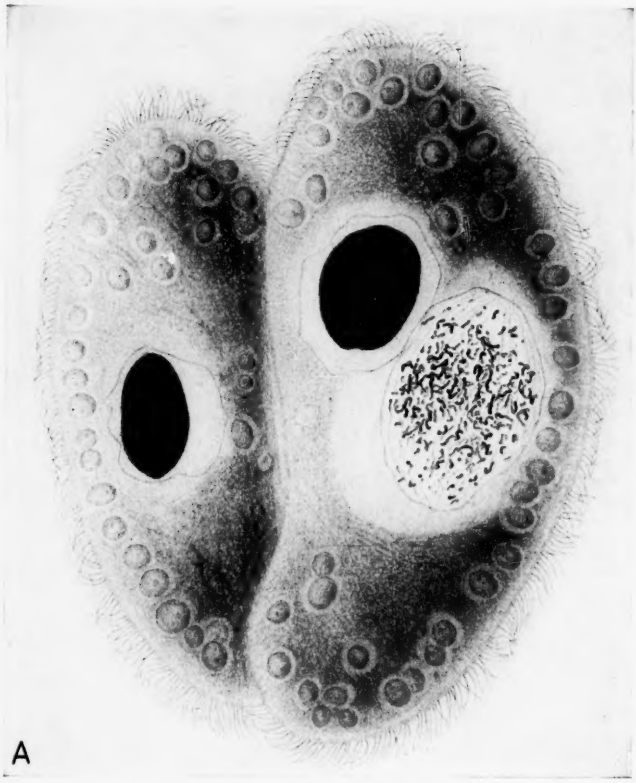
The Journal of HEREDITY



CONJUGATION BETWEEN PARAMECIA WITH AND WITHOUT MICRONUCLEI

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"Double-Twin" Quads as Heredity-Environment Guinea-Pigs

The "Darwin-Mendel" Battle in Soviet Russia

"Irregular" Phlox—a Fluctuating Character

People—How Come?

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Joyce Jeanette Jeraldine Joan

TWO PAIRS OF TWINS AT A SINGLE BIRTH

Frontispiece

Joyce and Jeanette appear to be identical; Jeraldine and Joan are unlike each other and the other two. Reared under a similar environment, these four babies will be an interesting study in how personalities differ in development because of heredity. Photograph by Galveston Chamber of Commerce.

THE BADGETT QUADRUPLETS

Identical and Fraternal "Twins" Born at Same Time Offer Another Approach to "Nature-Nurture" Problem

JOHN G. SINCLAIR
Department of Histology and Embryology, University of Texas

A YEAR ago four children were born to Mr. and Mrs. W. E. Badgett of Galveston, Texas. The children are all girls, and at the age of one year are very active normal babies receiving an unusual amount of public attention. Dr. W. J. Jinkins, who delivered them, has presented their gestational history. Dr. F. Garbade has kept a close record of their development and will present his findings as a pediatric problem. The author studied the placenta and collected some of the pertinent family history. He also made a preliminary set of finger and foot prints. Dr. I. Gardner has given the children one set of psychological tests.

On the basis of the menstrual history, Dr. Jinkins decided that the normal date of delivery would be March 12, 1939. An X-ray plate disclosed three skeletons. The presence of the fourth was not suspected. On the morning of the first of February the rupture of one amnion precipitated delivery. By calculation the infants were five or six weeks premature. Delivery was normal and brief. Jeraldine, Jeanette, Joyce, and Joan were born in that order with birth weights 3 lbs. 13¾ oz.; 3 lbs. 13¾ oz.; 3 lbs. 14 oz.; and 4 lbs. 9½ oz. Jeraldine and Joan had eyes distinctly lighter blue than the others.

Dr. Jinkins had taken considerable care to have the placental cords numbered as the infants were born. Unfortunately, the nurse removed the hemostats to which the tags were attached so that we know only that Joan was born from a single placenta and the others from a common placenta. The placenta (Figure 1) shows three cords marginally placed. One-third of this placenta has its own chorionic vesicle and the other two-thirds have a common vesicle. An injection demonstrates that the latter have a common circulation by several large superficial vessels. The third is firmly grown to the others along a scar line that is composed of decidua. Only a single small vessel passed across this scar line probably as a secondary anastamosis. The triple placenta weighed 1,255 grams, or an average of 418 grams for each. The separate placenta weighed 455 grams. These are nearly full normal weights for placentae at term but the infants were decidedly underweight, being below normal weights for single premature infants of the same age.

It seems then that one of the three, probably Jeraldine, is not identical with Jeanette and Joyce (Frontispiece). During the year Jeraldine's eyes have become hazel like the other two while Joan's have remained bright blue. Mrs. Badgett notices a distinct difference in disposition between Jeraldine and the others. Joan has maintained her advantage in weight and in learning to walk. Both Jeraldine and Joyce have each had a small hemangioma removed from their heads.

Twins in Parents' Families

The hereditary background of this twinning trait in the family is evident. The father, a blond like the daughters, had twin brothers. One died at the age of one week and we do not know whether they were identical. The mother, a brunette, has an identical twin sister, Mrs. Richardson. While they are identical even as adults it is interesting that they started life with one-half pound difference in weight. Mrs. Badgett's mother, Mrs. Harper, is very much like her in appearance. Mrs. Harper's brother has two sets of twins, two boys, and boy and

SEPARATE PLACENTAE

Figure 1

Quadruplet's placentae showing one pair with common circulation, one fused but with separate circulation and one separate placenta. Unfortunately, it is not known which of the quadruplets belonged to each of the placentae. Joyce and Jeanette, who on the basis of their similarities are identical probably had the common circulation.

girl. Again early death makes it impossible to state whether they were identicals. Mrs. Harper's sister's son, Mr. G. Miller, of New Mexico has triplet boys.

One problem raised here is the relative parts played by the father and mother in the twinning phenomenon. If ordinary twinning is the result of simultaneous double ovulation it is a maternal phenomenon only, so far as the present generation is concerned. I have the ovary of a young woman who was one of non-identical twins. This ovary shows a large number of double ovum primary follicles and indicates that had she lived she would have borne twins. If identical twinning is the result of a single morula producing two inner cell masses it is conceivable that paternal influence might play a part. In the case of our quadruplets identical twinning is present in the maternal heredity but is not certainly known in the father's family. The infants are blonds like the father. The maternal ancestry is mixed in this respect.

The unusual combination of identical and non identical twins in the same quadruplet group and the fact that they will receive continuous study while being given unusual opportunities for development makes this a very fine test case for ideas concerning the influences of nature and nurture in ontogeny.

◆

BIBLIOGRAPHY OF LOW-TEMPERATURE RESISTANCE

THE Imperial Bureau of Plant Breeding and Genetics published in November, 1939, a bibliography of more than 360 references on breeding for winter-hardiness. Many of the references listed are of a general nature, and therefore have not appeared in *Plant Breeding Abstracts*. The bibliography deals with techniques and factors in breeding for cold resistance, and also the physiological and other aspects of the problem.

References are classified according to subject and crops, with cross-references. There is also an alphabetical author index. The bibliography may be purchased direct from the Bureau (School of Agriculture, Cambridge, England) for one shilling six pence.

THE GENETIC FRONT IN THE U.S.S.R.

J. W. Pincus

SINCE the postponement of the World Genetic Congress, which was to have been held in Moscow in 1937, and since the absence of Russian geneticists from the 1939 congress in Scotland, the battle of "Darwinist" and "Anti-Darwinist" geneticists has been going on continuously. The daily Soviet press, as well as a number of the scientific publications has had letters and articles pro and con, mostly pro-"Darwinist,"—and the journal *Yarovizatzia* ("Yarovisation" or Vernalization) in particular has devoted many of its pages to the attacks upon "Mendelists-Morganisits, anti-Darwinists, and anti-Michurinists."

Many American scientists do not read Russian, and are entirely in the dark on this interesting controversy. Hence the following literal translations of abstracts of some of these articles will be valuable for themselves. Unless otherwise stated, they are from the pages of *Yarovizatzia* for the year 1939. This journal is edited by T. D. Lyssenko, and I. I. Prezent. The former is the originator of the mass-vernalisation, and is the Director of the All Union Institute of Genetics and Plant Breeding at Odessa (referred to in the abstracts as Odessa Institute). Lyssenko is also President of the Lenin's Academy of Agricultural Sciences. Prezent is his assistant at the Odessa Institute. The Journal is published six times per year. The headquarters of the Academy are located in Moscow, the Institute being part of the Commissariat of Agriculture of the U.S.S.R. The office of *Yarovizatzia* is: Moscow—64, B. Kharitonovski 21.

The Soviet Union Meeting on Plant Breeding and Seed Growing

On last February 27-March 4 (1939) a Conference was held in the office of the Commissariat of Agriculture of U.S.S.R. in Moscow on the subject of plant breeding and seed growing. This conference was attended by 150 leading Soviet geneticists, plant breeders, etc. The title under which this conference is reported: *Under the Banner of Darwin* is rather intriguing.*

A. J. Frankel, who is in charge of all production of elite seeds in the U.S.S.R., concluded his long report with the following: "The future work of plant breeding and seed production in U.S.S.R. will be built on the bases of Darwinism and Mitchurinism, and that the scientific-methodical work of this Bureau will be guided by the Lenin's Academy of Agricultural Sciences." Academician T. D. Lyssenko pointed out in his report that at the present time, there are two distinctly crystalized points of view on the nature of organisms. One point of view, which is presented by the followers of Mendel, do not change the environmental conditions do not change the nature of organism—the genotype. The other—which is now called in the Soviet Union the "Darwinian" point of view—recognizes that changes in heredity and genotype emanate from the environment. According to this point of view, the plants in the seed plots, or animals on the breeding farms must be provided with the best care and feed. The correctness of this Darwinian point of view, Lyssenko buttresses by many citations and examples, such as the fact that summer plantings of potatoes are improved from generation to generation. The wild Russian rubber producing plant "kok sagyz" has been converted into a cultivated plant with the help of such agro-technique. The experiments with changing the nature of wheat also demonstrate the same: that the genotypes of winter-hardy forms of

Yarovizatzia, No. 2 (23), 1939, pages 117-122.

wheat have been changed, and spring wheats have been changed into winter wheats in one or two generations. It is very important that the most favorable conditions be developed for the given process. The process of selection plays an important part in this connection.

In order to strengthen the changed process in the progeny, one must know how to produce future generations. Illustrating this, Lyssenko claims a number of experiments made by the Odessa Institute showed that the problem of directing mutations which has been found insoluble by Mendelists, has been solved: any quantities of winter wheat can be changed into spring wheat and vice-versa, and also winter wheat can be made more hardy.

Emphasizing the influence of environment (conditions of life) on the nature of the organism, Lyssenko stated that he demonstrated in many of his reports that the seeds gathered from "Stakhanov"* fields are better than the seeds gathered from low yielding poorly cared-for fields.

Thus it is possible, where it is impossible to get pure bred seeds from special seed producing farms, to utilize the seeds gathered from Stakhanov fields. It is concluded that there is no characteristic of a plant which cannot be intensified or minimized by agrotechnique or selection.

No 3:1 Ratios

Lyssenko also stated in his report, that Mendel's law of segregation of progeny of hybrids in a ratio of 3:1, is absolutely false; that Mendelists up till now have not and cannot furnish evidence which prove this "law."

The discussions which followed Frankel's and Lyssenko's papers, showed that for the majority of workers present, the theoretical controversy between the followers of Mendelism on the one hand, and the followers of "Darwin, Mitchurin and Lyssenko" on the other is already "past history."

The diagrams, tables, samples of seeds, etc., exhibited at this meeting all agitated for the Darwinian methods of plant breeding and seed growing. All these exhibits were said to have destroyed the Morganist-Johannsenists' claims concerning the limits of selection in pure lines, the identity of "Homozygous factors" of the pure lines, and their idea that it is impossible to improve pure lines by intervarietal crossing. The first attempt to use intervarietal crossing demonstrated the improvement of the variety, and the future work of seed growing in the U.S.S.R. will follow Darwinian direction.

I. C. Eikhfeld said that all persons who have to do with live plants in the field, must have the Darwinian point of view, while those who support the Morganistic, the metaphysical point of view, are those who are interested in heredity in general, particularly for the sake of "science." Some of the old well known plant breeders are simply following it by inertia, without utilizing this study for the benefit of the practice. All actual observations in nature and not manipulated, speak that Darwin, Mitchurin and Lyssenko are right.

A number of other representatives of plant breeding stations spoke of the success of their work along the lines advocated by Lyssenko. As there were present at this conference, a few of the followers of Mendelism-Morganism, they stubbornly defended their theoretical conceptions. The best of these arguments were presented by Academician N. I. Vavilov, chief of VIR.† Vavilov stated that he agrees that elite seeds should be grown under the best environments, but he added that he is strongly behind the theory of Mendel, the chromosome theory of Morgan, the teachings of Johannsen concerning the immutability of homozygotic factors

*STAKHANOV is the name of the Russian mine worker who introduced rationalization of mining of coal, and whose methods have been widely adapted to all other industries, including agriculture, where it means the intensive and the best modern methods of growing of seeds and crops.

of pure lines, the impotence of selection amidst plants with homozygotic pure lines and the teaching about the independence of genotype from the condition of the existence of phenotypes. Vavilov stated that all varieties of selected and hybrid plants were obtained as a result of utilizing Mendel's and Johannsen's teaching about pure lines. The foreign practices, particularly the achievements of the Svalof Station in Sweden are all based on Mendelism-Morganism. As to the teachings of Lyssenko, it reminds one of the theoretical views of the plant breeder Galett, who worked in the first half of XIX century. He also thought that by cultivation, improved methods of agro-technique, one could improve a variety. According to his opinion, Vavilov said, the real genetic science goes the way, indicated by Mendel, Morgan and Johannsen. The greatest event in genetics in the last ten years was the paper read by Muller at the Berlin Congress, where Muller announced that it is possible to change the genotype by the action of Roentgen rays. Vavilov thinks that the followers of Darwin, Mitchurin and Lyssenko are denying without any reason this example of "World Science."

Professor A. R. Jerbaak also stated that all Russian varieties of wheat were developed along the Mendelian-Morgan methods. He also tried to prove that the main points of Mendelism are really "strictly Darwinistic," and that both Timiriazev and Mitchurin admitted the scientific value of Mendelism.

The Two Americas

Prezent in his concluding remarks said that Johannsen was wrong, and that Timiriazev and Mitchurin were anti-Mendelists. He ridiculed the theory of Mendel: "Three like papa, one like mamma, or three like mama and one like papa." Lyssenko proved in his cross-varietal breeding tests with "Krymka" wheat the improvement made in that variety. Prezent concluded: "We are for the utilization of American experiments, but we must remember that in the range of biology there are two Americas: The America of the Drosophylist Morgan, and the America of the Creator of Varieties—Burbank†. So that if Vavilov is for America of Morgan, we, Darwinists, are for the America of Burbank," was Prezent's concluding remark.

Lyssenko in summing up, claimed that Vavilov is very contradictory in his remarks, on the one hand, he says that environments have no influence on the nature of the plant, but on the other hand, that he is not opposed to the increasing of "agrophones." The geneticists-Mendelists avoid the discussion of debatable questions, but usually make generalizations, and refer to foreign plant breeders and geneticists. Vavilov frequently refers to the scientist Roemer, who wrote his book under Fascism. I, said Lyssenko, am prejudiced against any present-day science in Germany, which claims that permanence and inalterability of races. The explanations of Vavilov, made at this conference are not clear, so scientifically indefinite, that only one deduction is made possible that "Varieties drop from the sky."

Casting Out the "Gene-Devil"

Lyssenko concluded that for the Soviet plant breeders the most urgent problem is the mastering of Darwinism, and the final liberation from Mendelism, as "Mendelism still sits inside of everyone of us."

The Commissar of Agriculture I. A. Benediktov agreed with Lyssenko and said that the future work of seed production will be based on Darwinian, anti-Mendelian theories. The following resolution passed by the conference, reiterates the above: "In the seed-growing in the U.S.S.R. plant breeding stations, the teachings of Darwin, Mitchu-

†VIR is the abbreviation for the All Union Institute of Plant Industry of which Dr. N. I. Vavilov is the chief.

rin, Timiriazev and Lyssenko should be the guiding principles, also the experiences of Stakhanov socialist fields should be taken into consideration. The work of all plant breeding stations should include varietal cross breeding, uninterrupted selection and the best possible environments (agro-technique). Elite seeds must be high yielding and must be compared with similar seed of this variety. All elite seeds must pass the comparative varietal tests conducted by the Government."

K. M. Dmitriev, who reports the conference in *Yarovizatzia* concludes his report with: "Such were the summaries of this Conference. The summaries speak quite clearly that Darwinism has won a durable victory in the seed growing and plant breeding work in the Country."

In addition to the above rather lengthy abstract of the Russian Genetic Conference in Moscow, the following brief abstracts from *Yarovizatzia* (No. 3) will throw some additional light on the "The Soviet Genetic Front." The segregation of hybrid generations is described in a number of articles. D. D. Brejnev of the VIR after quoting from Muller and others describes his hybridizing experiments, and concludes:

1. Lyssenko is absolutely right in his conclusion that the Mendel's Law ratio of 3:1 does not exist.

2. Occasionally this ratio does appear, but so do the ratios of: 4:1; 5:1; or 50:1, or 200:1, etc.

3. The progenies of some hybrids segregate not in any definite proportion, and, therefore, the seeding of second generation of the hybrids should be made not as a mechanical mixture, but according to the progeny of every plant of the first generation.

4. Segregation in the second generation practically disappeared in his experiments, as shown in the table.

5. The environments of the plant influence the progeny, quite contrary to the statement made by Muller.

6. Lyssenko's standpoint is again corroborated namely that "The development of hybrid plants always goes in that direction for which the conditions of the given field are more suitable."

In order to prove that Mendel's ratios are wrong, the article entitled "Misrepresentation of Mathematics for the Service of Mendelism" was written by a well known Russian Mathematician—E. Kolman. He proves that the figures used by T. E. Enin, who wrote an article on "Mendelism and Selection of Peas" are wrong. This article appeared in the Annals of Academy of Agricultural Sciences, and is reprinted in full in *Yarovizatzia*. Kolman concludes his article with: "The statistical method can be of great help to the biologists, but as a subordinate auxiliary means, and only after the biological regularities have been proven. . . . The attempt to substitute statistics for biology, which is being done by Mendelists, is anti-scientific and pseudo-scientific."

A number of articles on vegetative hybridization are given, which all prove the correctness of Lyssenko's views.

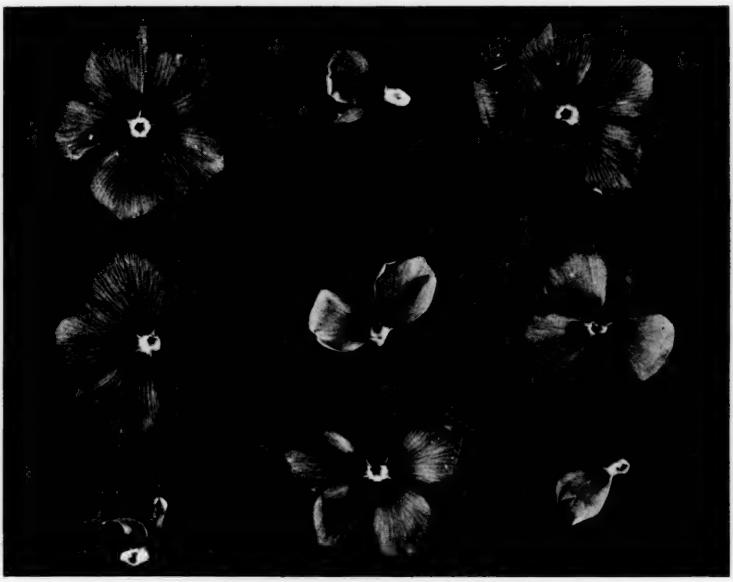
Another series of articles are devoted to much discussed subject—"Teaching Genetics in U.S.S.R."

Many letters by students of Soviet universities, as well as letters from professors and others, have appeared in the daily Soviet press. Many of these are reprinted or abstracted in the *Yarovizatzia*, but due to lack of space it is impossible to make extensive quotations. One article, written by A. V. Dementiev, and V. K. Kondzov under the title: "Teach Students Biology and not Mendelian Figments" expresses the tone of most letters, namely that the Mendelian theory, Morgan's and other teachings of modern foreign geneticists should be *eliminated* from the Russian textbooks, and the works of Darwin, Timiriazev, Mitchurin and Lyssenko used.

In Professor Delone's latest book, Sapegin's article on "Peculiarities of Segregation of Hybrids between Soft and Hard Wheats," as well as Vavilov and many others are severely criticized, and a demand is made to introduce new textbooks, closely connected with the ideologies of Darwin-Marxian theory.

IRREGULAR FLOWERS IN PHLOX*

J. P. KELLY



FLOWERS FROM A SINGLE PLANT

Figure 2

Of the nine flowers, only one is equipped with the normal five equal sized petals. The offspring from this plant were of two kinds—plants with normal flowers, and plants with varying proportions of irregular flowers. A single recessive gene appears to be the genetic basis for this condition, with environment greatly affecting the expression of the defect.

FLUCTUATING characters have an especial fascination to the geneticist, and this little article deals with a situation in phlox which turned out to offer an unexpectedly simple solution. The story begins with the complete set of fully-opened flowers found on one phlox plant on a specific day — June 6, 1937. The flowers are shown in Figure 2. Of the nine flowers only one had the five equal-sized lobes typical of normal phlox. This we symbolized by giving the plant a floral quotient of 8/9, a fraction wherein the numerator shows the number of irregular flowers and the denominator the total mature flowers of all sorts at the date on which it is examined.

From this plant we grew a progeny of 25 seedlings the following year. Data were collected on two occasions. On July 26, all 18 progeny plants in sufficient bloom for recording were rated "very irregular," repeating essentially

*Published as paper No. 968 of the Journal Series of the Pennsylvania Agricultural Experiment Station and as No. 128 of the Department of Botany.

the condition of the parent. On August 25, the balance of the family was recorded: three plants had wholly regular corollas (floral quotients of 0/6, 0/8 and 0/16); and four plants were rated irregular (floral quotients of 1/26, 4/58, 8/52 and 9/36).

Other groups illustrating the same tendency are:

Family	Examined	Regular	Irregular
127	July 18, 1938	0	7
127	August 3, 1938	2	5
161	July 15, 1937	0	6
161	August 3, 1937	11	6
167	July 23, 1938	3	20
167	August 7, 1938	6	1

Irregularity in these phloxes is a very fluctuating character in its expression. Not only may the degree of petal expression vary on one individual but among the sibs of the same family those blooming late would seem to be less favorable material for the development of irregularity than those flowering early. The fluctuation is toward a greater proportion of regulars or typical flowers in groups where only irregulars were anticipated.

This variation with age was shown on an individual plant which was recorded on August 30, 1938 with the fraction "2/4," meaning two out of a total of four flowers were irregular; on October 22, this same individual had 17 flowers with none irregular (0/17). Flowers of these phloxes fall about a week after blooming, so that the later set did not include any of the first set.

Many years of experience with ordinary regulars has proven "regularity" in flowers to be nearly non-varying as judged by comparing early and late flowers of one individual or early and late flowers in one inbred family. In some pedigrees, plants having slightly irregular flowers have been shown by breeding tests to be regulars.

This fluctuating irregularity has not been reported before in phloxes. It appeared for the first time in the F_2 generation in a pedigree relating to picta patterning, arising unexpectedly — presumably as a mutation. My records do not show whether it is a recent or remote mutation.

Hybrids With "Regulars"

Many crossings were made between plants with regular and those with irregular flowers and these gave a first hybrid generation of 157 plants. Close inspection showed that 147 of these had exclusively regular flowers while 10 were rated as slightly irregular. Essentially, the regular condition is dominant to the irregular.

As this experiment proceeded it was thought possible that gene differences might be correlated with variation in grade of irregularity, so an irregular segregate having less than 50 per cent of its flowers irregular was classed as "slightly irregular" in Tables I^s* and II^s. An irregular segregate with 50 per cent or more of its blooms irregular was placed among the "very irregular."

The total for all F_2 families was 1,005 plants of which 808 were regular, 162 slightly irregular and 35 very irregular. The distinction into two types of irregular seems to have no gene basis and so we are stating our ratio to be 808 regulars to 197 irregulars.

We have arrived at the conclusion that only a single pair of genes is involved in the distinction between regular and irregular and that due to the great variability toward regular of the irregular type, there was a tendency for more of the regular to appear. Instead of a 3:1 ratio, something like four regulars to one irregular were counted.

The F_3 Generation

To test the reasonableness of the hypothesis just stated, Table I^s, which summarizes data on the F_3 generation, should be examined. One notes that the first 15 families (group *a*) give ratios to be expected if the immediate parents

*The two detailed tables have been afforded supplementary publication as Document No. 1341 of the American Documentation Institute, 2101 Constitution Ave., N. W., Washington, D. C. Enclose 25 cents for the tables on microfilm, enlarged to readable size with hand-viewer, or 70 cents for photoprints, readable without mechanical aid.

(F_2) of these groups, all classified as regular, were simple hybrid regulars.

The next nine families of the table (group *b*) show an F_3 distribution resembling that of the first 15 but the F_2 parents were classified as irregular. Where recorded, the irregularity was slight. The data in group *b* would point to the F_2 parents here being genotypically like those of the *a* group.

The next section of F_3 families (group *c*), 18 in number, is considered to be wholly irregular genotypically. The light control of the genes for irregularity permits some F_3 plants holding these units to fluctuate even into plants looking fully regular.

Following this come 49 families representing true-breeding F_2 regulars (group *d*) which rarely give fluctuants toward slight irregularity.

Group *e* of 13 families, descended from F_2 parents classified as slightly irregular. The composition of the F_3 is such as to suggest that these particular "slightly irregular" plants were genotypically homozygous regulars.

Lastly is a lot of three families, group *f*, whose F_2 parents were phenotypically regular, but whose genotype was "irregular." These F_2 regulars were therefore regular fluctuants of irregular.

Table II[8] summarizes all data of F_4 or F_5 generation level in pedigrees involving the irregular flower. The group letters *a, b, c, d, e, f* have the same significance as in Table I. In general, Table II confirms the inferences drawn from the data in Table I.

Babcock and Clausen (*Genetics in Relation to Agriculture*) present a formula which summarizes the problem of genetics in any organism: $C=f.(H.E.)$, which they hold to mean that the phenotypic character is a function of both Heredity and Environment. In the case of floral irregularity in phlox the hereditary aspect is simple, being a single pair of genes. The character associated with this gene pair varies due to the relatively stronger influence of the environment in which it is working. The character "irregular" stands in marked contrast to the character "cuspidata" in the same species of phlox, reported previously. Cuspidata flowers do not vary as do the irregulars with time of appearance on a plant or with untoward growing conditions. The character cuspidata is more subject to the *H* and less to *E*.

The gene pair studied in this article we propose to designate *V-v* in allusion to the great variability associated with its expression when in recessive condition (*v-v*), the genetic constitution of plants with irregular flowers. The general run of annual phlox with stable regular flowers would be *V-V*.

One is reminded of a character in the common snapdragon reported by Baur It also rested on a single recessive gene designated by him *p-p*. One plant with *p-p* might show fully normal (irregular) flowers, radially symmetrical flowers and intermediate ones. Baur found a positive correlation between the formation of two-lipped flowers and poor nourishment, but the detailed correlations with such a comprehensive entity as "environment" he was not entirely able to solve.

✦

PEOPLE—HOW COME?

KNOW thyself" said the Greek philosopher a couple of thousand years ago, and his followers even made small beginnings in realizing that estimable purpose. Later the scientific study of man came to a standstill until fairly recent times. Alexander Pope ushered in the modern era by pointing out that "the proper study of man is man," but he did not live long enough to see this excellent advice put to very much use. He stood at the dawn of a new day, and within the last century man has increasingly come to consider himself worthy of being understood.

Naturally the job has not been an easy one. Man, the observer, is not in the best position to view objectively

the writhings and squirmings of man the experimental material. As a matter of fact, man's experiments on himself have had to be almost exclusively a waiting game—to see what fate would turn up. The problem has been further complicated by the fact that throughout the ages, in reverse proportion to the lack of exact knowledge about man or about life, there has never been any scarcity of baseless theories and fantastic fairy tales. The anecdotal approach—"I recall," and "grandfather said"—makes no bones of proving the earth flat, or maleria due to "night air," and our poor friend Homo has eagerly laid himself open to endless abuse by the theorizers and the dogmatizers. Not until experimental biology had laid an adequate foundation of knowledge regarding vital processes could man exorcise these ghosts of illusion. Only by knowing life has man begun to know himself.

So the problem of getting anywhere with man's proper study has been a difficult one. When Lincoln opined that "the Lord must love common people: he makes so many of them," he probably had never heard of a British divine who not so long before had been puzzled by this same phenomenon, and had tried to understand the dynamics of the problem which Mr. Lincoln so blandly short-circuited. Perhaps Mr. Lincoln did not realize that the Nineteenth Century's vast production (or at least mass survival) of people was a relatively new phenomenon. For generations the number of people had not greatly changed until that amazing century of progress between 1820 and 1920 in which the population of Europe and America did not merely increase, but doubled and redoubled.

Malthus' doubts infringed on Mr. Lincoln's world hardly at all. They are accepted today as a somewhat sombre backdrop to much of the stage of our doing and thinking and trying to make a brave new world out of the hodgepodge of hopes and fears, stupidities, superstitions, hatreds and loyalties, which have furnished the prologue to World War II.

"Wherefore Choose Ye Life"

In spite of the disruption and disaster which seem to be sweeping over our world, we are privileged to watch the development of one great contribution to human progress. We have begun to set up the machinery to come to grips with life itself, and really put Pope's dictum to work. All through the long and checkered career of our race, life has been the one inscrutable mystery. Man has accepted birth and growth and death as unknowable and untouchable super-phenomena, and he has paid in a multitude of ways for his ignorance and for his fear of learning about life. Today our outlook is changing greatly. An epidemic is no longer a visitation of an Inscrutible Providence: It is caused by a microbe or virus. We don't burn incense and shoot off firecrackers to scare away evil spirits when yellow fever strikes: we drain swamps to get rid of tiny winged angels of death with unpronounceable Latin names. We know now how the human life cycle works and we are hot upon the trail of ways and means to conquer disease, and ultimately even to eliminate hereditary defects and disabilities. As a people we no longer accept the birth of an unwanted baby as necessarily for the best, for the parents, for the child, or for society. This kind of knowledge of life, and of coming to grips with problems of life, is utterly new and unique in the history of our race.

Our first great successes have been in coming to grips with death. In a generation, the chances of a baby's living to be one year old are five times what they used to be. That is only part of the larger problem of coming to grips with life as well. Our job is only half done until we give thought to what effect these changes may have on the future history of our race. This is a daring adventure we have entered upon and the end is not easy to foresee. Certain it is that this changed outlook and the new knowledge we are accumulating every day makes the question of what kind of people we are, and of what

kind of people we are likely to become, a matter which we ignore or deny at our peril.

Meet the "Mean Man"

For that reason, books which enlighten the nontechnical reader about population problems are of the utmost importance. We still suffer overmuch from the priestly tradition of the magic of big words. We need to stop hiding behind them, and to tell what we know about life in terms anybody can understand. Two noteworthy recent contributions to this field by leaders in population research deserve to be widely read.* The books are very different in content and outlook, and are addressed to different audiences. Professor Fairchild's book is intended as an introduction for the intelligent lay reader. It attempts in the author's stimulating style to give without tabular fanfare the background of population theory and the facts which are today established about population growth and decline. The reader is introduced to populuation statistics and how they are used to estimate the changes in the number and the kind of people. Quality and quantity is discussed in Professor Fairchild's provocative (to some readers and in some connections, infuriating style). It is not a book calculated to evoke one hundred per cent agreement by Professor Fairchild's co-workers in the field of population research. Any of them with a drop of sporting blood in their veins have to admit that it is a valuable addition to the literature which any layman can read with profit and in this reviewer's estimation with more pleasure than many attempts to tell the world what the demographers have learned about that valuable statistical fiction, "the mean man,"—how he is born, marries, reproduces and dies.

His concluding chapter, on eugenics, reviews the possibilities and pitfalls. How to get prospective brides and grooms to drink after they have been led to the eugenic font puzzles Professor Fairchild as it does most serious students of the question. And yet he holds that quality is so important that somehow love, which has traditionally laughed at locksmiths, must be "sold" on the idea of taking eugenics seriously—if not too solemnly.

Not-so-Fertile Homo

The other contribution to our knowledge of population is more technical in nature. In it, Dr. Raymond Pearl takes us on a tour of the biological factors underlying population growth. Thus it serves as a companion volume to his earlier *Biology of Death*. This is perhaps not a book for every drawing room, but intelligent bedrooms will find it interesting—nay fascinating—and no biological laboratory should be without it. Furthermore, any person who undertakes to discuss any aspect of population growth and decline should read this book before proceeding. In it are contained probably the most detailed and exhaustive data available on the effectiveness of contraceptive techniques and on the troublous question of just how fertile a creature mankind was created on that distant day when he set forth to be fruitful and people the earth. For Dr. Pearl is convinced that declining birth rates are not due to any lessening of this ancient faculty, but to human ingenuity in curbing it. Pearl's data show as a matter of fact that our friend Homo seems to be surprisingly lacking in fecundity, rather than to be bubbling over with it, as popular belief, strengthened by the testimony of a multitude of fiction writers, lead us to believe. If Professor Pearl's statistics are as accurate and as representative as he believes them to be, the birth of a human baby represents the crowning achievement of an amazing amount of hopeful perseverance. Periods of rapid population growth appear to represent a simply astonishing amount of sexual activity.

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*Fairchild, H. P. People. Pp. 315. $3.00. Holt, N. Y., 1939.

Pearl, R. *Natural History of Population*. Pp. 416, price $3.50. Oxford University Press. N. Y., 1939.

So contrary to the accepted situation are his findings that Dr. Pearl seems almost to be arguing away his own doubts in the detail with which he buttresses his reasons for considering that his low estimate of human fruitfulness is not underdrawn. His data were all compiled from case-histories of fertile couples, so that there is no question of sterility being involved in his results. The instances of outstanding erotic athleticism which he has also brought together buttress his view. It must be admitted that it is something of a modern marvel that man has been able to find the time to make himself available for study in such numbers as exist today.

The reviewer can't help but wonder a bit about one aspect of this situation. It appears that wars are often accompanied by a crop of war babies a decent interval after hostilities have gotten under way. Yet if Pearl is right this would seem to be theoretically impossible or to represent a miracle of long-range paternity. So perhaps the novelists have a bit of truth on their side after all—some still unapprehended principle that has escaped the necessarily rather ponderous bedroom-stalking of the biometricians.

Like Professor Fairchild's book, this is the product of a skillful and practiced hand. It also is challengingly and provocatively written. It is a unique contribution to human biology which should do much to dispel the cocksureness of many pronouncements in this field about which we know much more than we used to, but in which in so many ways, a little knowledge is likely to be a very dangerous thing. And it might be noted that all of us—even the experts—are still by that definition in very great danger!—R. C.

◆

ROLE OF THE GOLGI BODIES

SCARCELY any information is available at present pointing to the conclusion that the Golgi bodies play a role in the transmission or in the mechanism of expression of hereditary traits. Yet, there are good reasons to believe that this is due to lack of observations rather than to the actual absence of causal relationships. The facts that mitochondria and Golgi bodies are cell constituents of all orders of animals from protozoa to mammals, and that their appearance changes with the type or degree of cellular activity, indicate that they play a fundamental role in cellular physiology. Even more impressive to the geneticists are those observations which indicate that the mitochondrial and Golgi material is about evenly distributed during cell division. Further, some slight evidence has been brought forward which suggests the possibility that the Golgi bodies may play a role in embryonic determination. It is true that in all these respects a great deal more evidence is needed before generalizations can safely be made. What we do know is suggestive enough, however, to make it desirable that geneticists should familiarize themselves with the problems, and for this purpose the monograph by Hirsch* should be useful. The author gives an excellent summary of our present knowledge concerning morphology and physiology of the Golgi bodies. The book is well illustrated and contains a complete literature list (91 pages).

W. LANDAUER.

Storrs, Conn.

HIRSCH, G. C. *Form- und Stoffwechsel der Golgi-Körper.* Protoplasma-Monographen vol. 18, XII and 394 p., 233 figs. Cloth, 28 marks. Berlin, 1939.

POLYPLOIDY AND ITS ORIGIN IN PARAMECIUM*

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POLYPLOIDY, which is taking an increasingly important place in the genetics and physiology of plants, is relatively very rare in animals. Fankhauser[1] has recently listed in this JOURNAL the known cases in animals and described triploid and tetraploid salamanders. The author has for the past several years been studying chromosomes in different species of Paramecium, including *P. aurelia, P. caudatum,* and *P. bursaria.* This paper deals chiefly with polyploidy in *P. bursaria* and also considers the existence of polyploidy in *P. caudatum.*

Material and Methods

Seven races of *Paramecium bursaria* were used for the present study: *Fd, Fl,* and *Fb,* which were collected along Falls Road near Baltimore, Maryland; McD_3, from a locality near Baltimore; *Gr*14 and *Gr*6, from North Carolina; *S,* from Johns Hopkins University campus. These seven races belong to seven mating types of Group II (see Jennings[2]). For these races of *P. bursaria* I am greatly indebted to Prof. H. S. Jennings.

The animals used in the present study were cultured in essentially the same manner as that described by Jennings.[2]

Under appropriate conditions, animals belonging to different races will immediately agglutinate when mixed, and conjugating pairs are soon formed. Temporary aceto-carmine preparations were made from time to time to follow the progress of conjugation. When the desired stage (late prophase of the first pregamic division) was reached, other conjugating pairs were fixed in hot Schaudinn's fluid containing glacial acetic acid (95 cc. Schaudinn's fluid plus 5 cc. glacial acetic acid), and subsequently stained in iron haematoxylin. Feulgen's technique was also used.

Before the present study on the chromosomes in six races of *P. bursaria,* the writer had examined the chromosomes in a race of *P. caudatum.* The former study was largely carried out at the Johns Hopkins University, the latter was done at Yale University.

All the drawings were made with the aid of a camera lucida. The writer is indebted to Mrs. Laliah C. Runyon for her assistance in preparing drawings of *P. bursaria,* most of which were made during 1939 (some earlier), and to Miss Margaret Shepard, who assisted me in making drawings of chromosomes in *P. caudatum* during the summer of 1937.

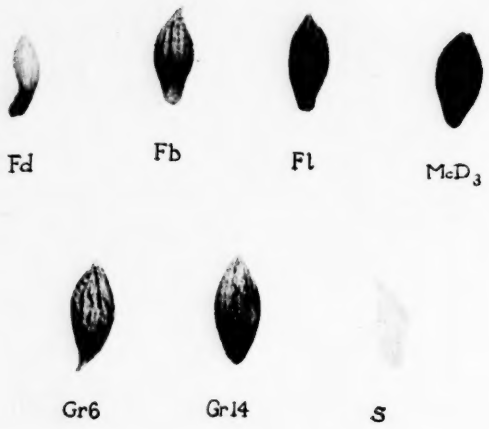
The writer is also indebted to Professors H. S. Jennings, L. L. Woodruff, and Robert Hegner for critical reading of the manuscript.

Micronuclear Variation in Paramecium bursaria and Its Significance

The micronuclei in different races of *P. bursaria* may differ a great deal in size and in the quantity of chromatin they contain. Among the six races (*Fd, Fb, Fl,* McD_3, *Gr*6, *Gr*14) carefully studied, race *Fd* shows an unusually small micronucleus containing a very small quantity of chromatin in contrast with the relatively large size of the micronucleus present in the other races. Such

*Contribution from the Department of Zoology, Johns Hopkins University, and the Department of Protozoology, School of Hygiene and Public Health, Johns Hopkins University.

This work was aided by grants-in-aid from the National Academy of Sciences and from the American Philosophical Society.



MICRONUCLEI IN SEVEN RACES OF P. BURSARIA

Figure 3

Vegetative resting micronuclei of seven races of *P. bursaria*. See text for further explanation. 1640×.

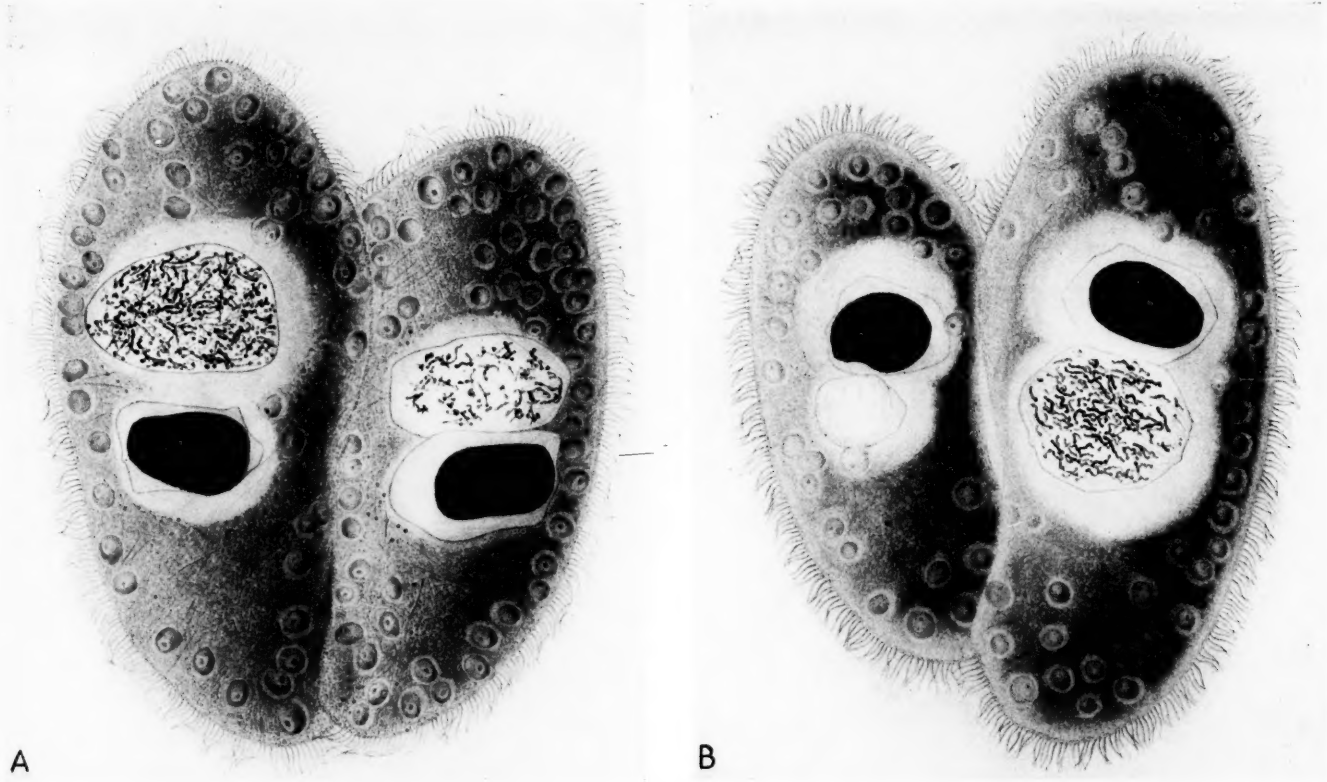
differences in size and in the quantity of chromatin are constant and characteristic and are correlated with the difference in chromosome number. The size, shape, and chromatin distribution of the resting micronucleus in each race may be described in some detail.

(1) *Fd:* The micronucleus in this race is unusually small and inconspicuous (Figure 3). It is slender, elongate, pointed at one end and rounded at the other, and often shows its greatest diameter at the region between the middle and the pointed end. It stains lightly, containing a small quantity of chromatin concentrated at the rounded end.

(2) *Fb:* The micronucleus of this race is large and conspicuous (Figure 3). It is somewhat spindle-shaped, the mid-region having the largest diameter. The region near the middle shows a heavy concentration of chromatin and hence this region is more darkly stained, whereas the two polar regions are relatively lightly stained. The chromatin substance, as seen in the less intensely stained areas, is in the form of thin, granular strands regularly arranged parallel to the longitudinal axis of the nucleus.

(3) *Fl:* The micronucleus in this race is large and conspicuous (Figure 3). It is somewhat spindle-shaped, and the region with the greatest diameter is near the middle. One end is sharply pointed, the other end either blunt or also pointed. At or near one end there is often a slight concentration of chromatin and hence this region takes a deep stain. The chromatin substance seems to be in the form of relatively heavy, irregular strands arranged more or less parallel to the longitudinal axis of the micronucleus.

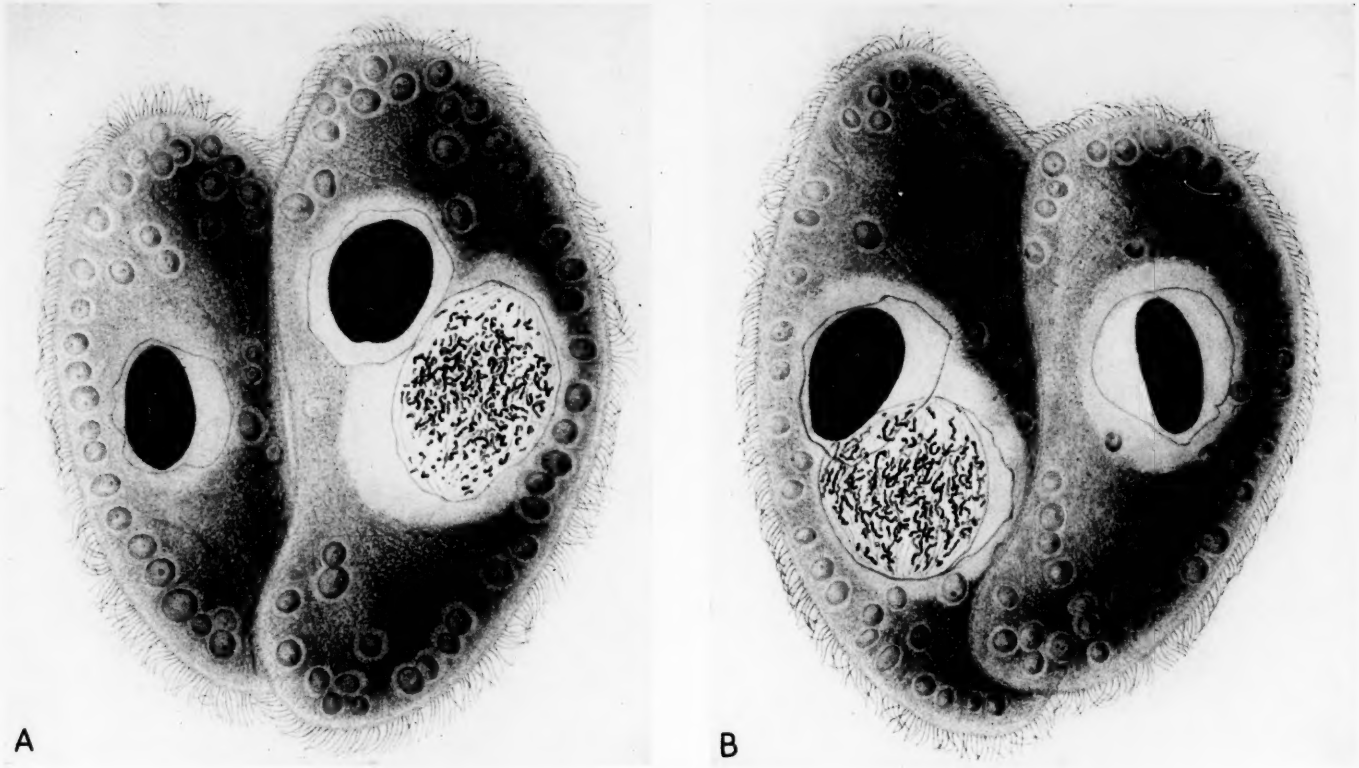
(4) *McD3:* Among the five races with a large and darkly stained micronucleus, the micronucleus of *McD3* is the most conspicuous and stains most intensely (Figure 3). The micronucleus is, in the majority of animals, ovate, relatively short and broad as compared with the micronuclei of five of the other races. The mid-region has the largest diameter. The internal structure of the micronucleus is difficult to make out because of its intense chromaticity. The chromatin substance seems to be in the form of fairly thick, granular strands, more or less closely packed, lying parallel to the longitudinal axis of the micronucleus. Here and there within the micronucleus the chromatin strands seem to be clumped into bundles which vary in thickness. Near one end of the micronucleus the chromatin strands are more closely packed, hence this region takes the heaviest stain, and often appears solid black. Furthermore the peripheral region of the micronucleus often takes a very



CHROMOSOMES IN PARAMECIUM BURSARIA

Figure 4

A—Conjugation between races McD_3 and *Fd*. Late prophase of the first pregamic division. The conjugant on the left belongs to race McD_3, a polyploid form: note the very numerous chromosomes totalling several hundred. The conjugant on the right belongs to race *Fd* which has apparently about eighty chromosomes. *B*—Conjugation between races *Fb* and *S*. Late prophase of the first pregamic division. Note the numerous chromosomes in the conjugant (*Fb*) on the right. The conjugant on the left, belonging to race *S*, has a "ghost" micronucleus. (The darkly staining macronuclei take no part in conjugation). Both figures 1093×.

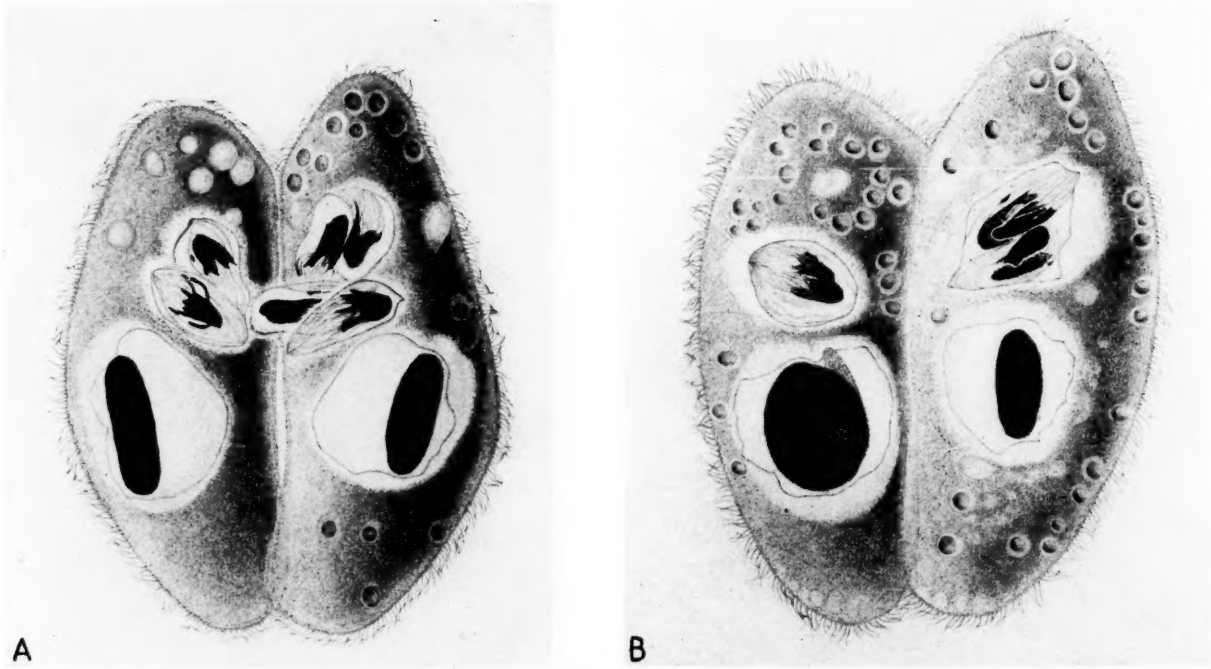


CONJUGATION BETWEEN POLYPLOID RACES AND THE RACE *S*

Figure 5

Conjugation between individuals of two polyploid races of *P. bursaria* (*Gr*6 shown in *A* and *Gr*14 in *B*) with individuals of the *S* race, which either has a "ghost" micronucleus, or lacks a micronucleus entirely, as do the two animals shown here. In spite of the nuclear disparity between races, conjugation proceeds normally. (See page 189 of this issue of the JOURNAL.) Both figures 1093×.

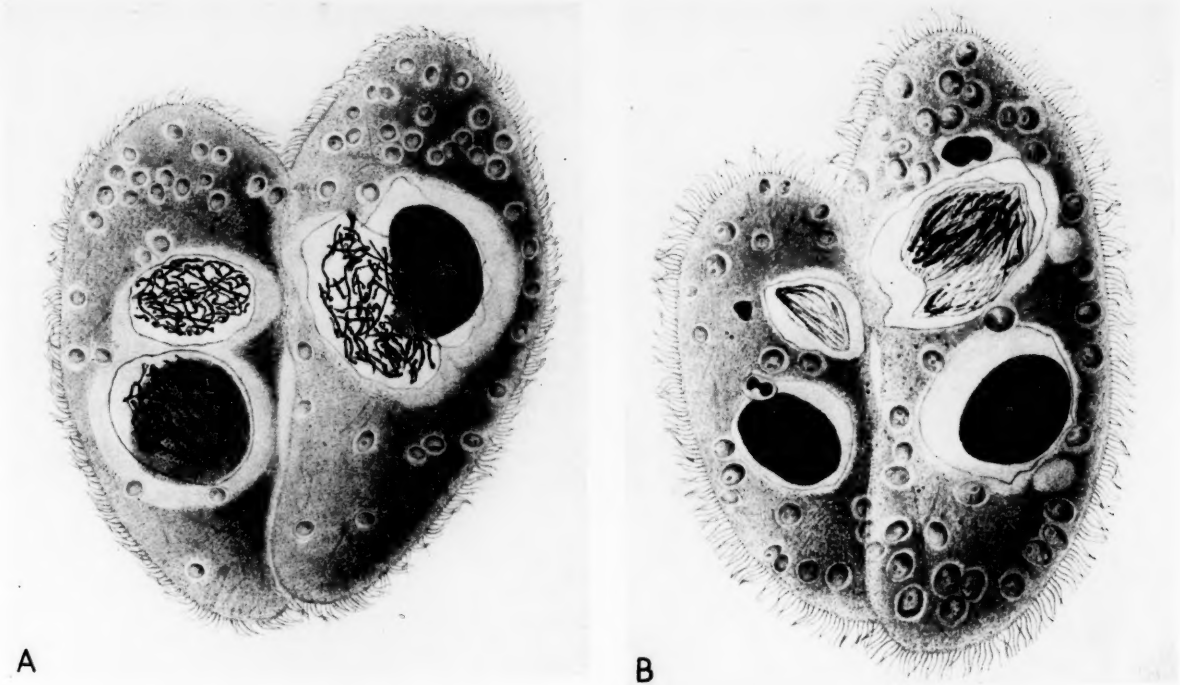
jugation proceeds normally. (See page 189 of this issue of the JOURNAL.) Both figures 1093×.



SUPERNUMERARY PRONUCLEI OF PARAMECIUM BURSARIA

Figure 6

A—Supernumerary pronuclei, showing six pronuclei in two conjugants, the usual number being two in each conjugant. Exchange of pronuclei is in process. *B*—Fusion of four pronuclei in one conjugant and of two pronuclei in the other, showing a later stage in conjugation. Both figures 1093×.



ANOMALIES IN CONJUGATION OF PARAMECIUM BURSARIA

Figure 7

A—Conjugation between an animal with a single micronucleus (the usual number) and an animal with two micronuclei. Late prophase of the first pregamic division. *B*—Conjugation between races McD_3 and *Fd*, with failure of the migratory pronucleus in the conjugant on the right to move to the conjugant on the left. The migratory pronucleus of the conjugant on the left (*Fd*) has already moved to the conjugant (McD_3) on the right. Hence there are three pronuclei in the conjugant on the right and only one pronucleus (stationary) in the other. The three pronuclei appear to be in the process of fusion. Both figures 1093×.

heavy stain, indicating that the chromatin is more heavily concentrated in this region.

(5) *Gr6*: The micronucleus of this race is large and conspicuous (Figure 3). It is long and spindle-shaped, often pointed at both ends, with the largest diameter near the middle. There seems to be a heavy concentration of chromatin near one end. The chromatin is in the form of irregular, granular strands lying more or less parallel to the longitudinal axis of the micronucleus.

(6) *Gr*14: The micronucleus of this race is large and conspicuous (Figure 3). It is frequently spindle-shaped, the mid-region having the largest diameter. One end of the micronucleus is pointed, the other end is either blunt or also pointed. The chromatin substance often appears to be more concentrated toward one end of the nucleus. The chromatin is in the form of thin, granular strands, lying more or less parallel to the longitudinal axis of the micronucleus.

The constant difference in size between the micronucleus in *Fd* and the micronucleus in five of the other races is significant for it is correlated with the very great difference in the number of chromosomes. Race *Fd* (Figure 3), which has a relatively small micronucleus, contains a relatively small number of chromosomes, while each of the other races (polyploid) having larger micronuclei, has several times as many. It seems clear that within the same Group (or variety) of *P. bursaria*, the size of the micronucleus and the quantity of chromatin are correlated with the number of chromosomes. The difference in size of the micronucleus between race *Fd* and the five other races is constant, even though there is some variation in the shape and structure of micronucleus in each race.

During conjugation, it is noted that the pronuclei in the polyploid races are also larger and contain a much greater quantity of chromatin than those in race *Fd*. The macronuclei do not show such great diversity in size.

Chromosome Numbers in the Six Different Races of *P. bursaria*

Most of the animals belonging to race *S* have no micronucleus, but some animals show a "ghost" micronucleus which does not stain with haematoxylin (Figure 3). Such a micronucleus in an ordinary vegetative individual is difficult to find, but during conjugation the "ghost" micronucleus, like the typical micronucleus, becomes greatly swollen in the first pregamic division and hence it can be seen more readily.

Since the races *Fd* and *S* differ so markedly in the nuclear apparatus from the other five races, it is a simple matter to identify members of a conjugating pair in such matings as $McD_3 \times Fd$, $Gr14 \times S$, etc. In the mating of McD_3 and *Fd*, one of the two conjugants (McD_3) always shows a large number of chromosomes, whereas the other conjugant (*Fd*) shows a much smaller number (Figure 4*A*).* In the mating of *Gr*14 and *S*, one conjugant (*Gr*14) always shows a large number of chromosomes, the other (*S*) is either without a micronucleus (Figure 5*B*) or shows a "ghost" micronucleus. Thus by mating either race *Fd* or *S* with any of the other five races it is possible to identify with certainty each conjugant as belonging to a particular race and to obtain the chromosome number of that particular race.

In the present investigation the following matings were made: $McD_3 \times Fd$ (Figure 4*A*); $Fb \times S$ (Figure 4*B*); $Fl \times S$; $Gr6 \times S$ (Figure 5*A*); $Gr14 \times S$ (Figure 5*B*).

The most favorable stage for the counting of chromosomes is the late prophase of the first pregamic division during conjugation, at which time the micronucleus becomes very greatly enlarged, even larger than the macronucleus in the same animal, and the chromosomes are relatively more dispersed, making it possible to ascertain their approximate number. In these six races of *P. bursaria*, the late prophase stage of the first pregamic division occurs about 20 to 22 hours after the onset of conjugation, at a temperature of 26° to 28° C.

*Thus it is clear that a race of *P. bursaria* with a low chromosome number can conjugate with a race having a high chromosome number. (For a detailed description of such conjugation, see pages 186 and 189 of this issue of the JOURNAL). Two races of *P. bursaria*, each having a large number of chromosomes, will also conjugate.

The chromosome number in race *Fd* (diploid?) is apparently about eighty (Figure 4*A*), while the chromosome number in the five other races (polyploid) is much larger, running up to several hundred (Figures 4, 5). It appears that some of these polyploid races have a higher chromosome number than other polyploid races. The determination of approximate chromosome number in each race is now in progress.

It is not certain whether the race *Fd* is a diploid or polyploid race. Further investigation will be necessary to ascertain this point.

Origin of Polyploidy in Paramecium

The most plausible explanation of the origin of polyploidy in Paramecium lies in the fusion of more than two pronuclei (Figure 6*B*). In 1937, the writer found in *P. bursaria* no less than 23 cases of the presence or fusion of three or four pronuclei in each conjugant (Figure 6). In such conjugations the number of chromosomes is increased. The polyploid races in *P. bursaria* with several hundred chromosomes probably show the cumulative effects of several conjugations of this unusual type which have occurred at various times in the past. The origin of this increased number of pronuclei in a conjugant has three possible explanations: (1) the failure of one of the two products of the first or second pregamic division to degenerate; (2) the conjugation between a normal animal with one micronucleus and an animal with two micronuclei (Figure 7*A*); or (3) the failure of the migratory pronucleus in one of the conjugants to migrate to the other conjugant (Figure 7*B*), so that there are three pronuclei in one conjugant and one pronucleus in the other (these three pronuclei appear to fuse).

Frequency of Polyploidy in *P. bursaria*

In addition to the six races reported here, four other races of *P. bursaria* in Group II were similarly studied. These latter four races are all polyploid.

The fact that in Group II of *P. bursaria* nine races out of ten so far studied are polyploid seems to indicate that polyploidy is common in this species. Furthermore, within a period of two months the writer found no less than twenty-three cases of the presence or fusion of three or four pronuclei in each conjugant. Many more races belonging to all three groups of this species would have to be analyzed cytologically before any definite conclusion as to the frequency of polyploidy in this species could be made.

CHROMOSOMES IN PARAMECIUM CAUDATUM

Figure 8

Chromosomes in a polyploid race of *P. caudatum*. Anaphases of ordinary vegetative reproduction (2516×).

Polyploidy in *P. caudatum*

Polyploidy evidently occurs also in *P. caudatum*, judging from the recent report of Penn,[4] the work of Calkins and Cull,[5] and the writer's study. Penn

found that the diploid number of chromosomes in his race of *P. caudatum* is 36, while Calkins and Cull reported more than 150 chromosomes in their race of this species. The race of *P. caudatum,* which the writer had examined, has a large micronucleus and numerous chromosomes (Figure 8). In all likelihood this race of *P. caudatum,* like the race of Calkins and Cull, is polyploid.

Discussion

1. *Polyploidy and Chromosome Numbers in P. bursaria.*

It is shown in the present investigation that certain races of *P. bursaria* have as many as several hundred chromosomes. The presence and fusion of more than two pronuclei is suggested as an explanation for the origin of polyploidy in Paramecium. A question arises in this connection: Is the highest chromosome number in Paramecium limited to several hundred? If polyploidy is due to the occasional presence and fusion of more than the usual two pronuclei, could such fusion of supernumerary pronuclei and a subsequent increase in chromosome number be repeated in successive generations so that races with perhaps more than a thousand chromosomes might be produced? There are three possible answers to this question.

(1) It is of course possible that races of Paramecium with more than a thousand chromosomes may be found. Certain protozoons are reported to have as many as 1,500 chromosomes. (For a list of chromosome numbers in Protozoa see Belar[6]). It would not, therefore, be surprising to find races of Paramecium having a larger number of chromosomes than several hundred.

(2) The above possibility may be only slight, since there are certain possible limiting factors. As shown in some higher plants, there is an optimum for the increase in chromosome number. Beyond such an optimum the organisms become weak or non-viable (see Müntzing[3]). A similar situation may exist in Paramecium.

(3) A second limiting factor exists against the possible presence of races of Paramecium with very many chromosomes. This factor concerns the results of conjugation of polyploid animals. A polyploid animal might not be able to retain the same high chromosome number after conjugation. When a polyploid animal conjugates with a diploid animal, the former would have a lowered chromosome number as a result of such conjugation. This probably holds true for conjugation between a polyploid animal having a high chromosome number and a polyploid animal having a lower chromosome number. When a polyploid animal conjugates with an amicronucleate animal, the chromosome number in the polyploid animal would probably be reduced to half as a result of such conjugation. Even when a polyploid animal conjugates with another polyploid animal having the same chromosome number, there would be no further increase in chromosome number unless there is again the unusual formation and fusion of more than two pronuclei.

2. *Possible Relation between Polyploidy and Long Periods of Immaturity in Certain Races of P. bursaria.*

It would be of interest to ascertain whether polyploidy might be related to the long period of immaturity in certain races of *Paramecium bursaria,* some of which, according to Jennings,[2] require many months to reach maturity. In higher plants, it was shown that polyploid races are often slow-growing (see Müntzing[3]).

Summary and Conclusions

1. The micronuclei in different races of *Paramecium bursaria* may differ in size and in the quantity of chromatin they contain. Such differences are constant and are correlated with the difference in chromosome number. Among six races studied, one race (*Fd*) shows an unusually small micronucleus while the other five races (*Fb, Fl, McD*$_3$, *Gr*6, and *Gr*14) all have large and conspicuous micronuclei.

2. Race *Fd* has apparently about 80 chromosomes, while in each of the other

five races the chromosome number is very much greater, running up to several hundred. (Nothing is known about the chromosomes in race *S.*)

3. Polyploidy, resulting from the fusion of more than two pronuclei during conjugation, is almost surely the explanation of this increased number of chromosomes in *P. bursaria* because a number of conjugants with three or four pronuclei have been found and cases have been observed in which these three or four pronuclei fused. In such conjugation the number of chromosomes is increased. The races with several hundred chromosomes probably show the cumulative effects of several conjugations of this unusual type which have occurred at various times in the past.

4. Judging from the data at hand, polyploidy seems to be a common phenomenon in *P. bursaria.*

5. Conjugation in *P. bursaria* occurs between a race with a low chromosome number and a race with a high chromosome number. Conjugation also occurs between races each having a large number of chromosomes.

6. Polyploidy evidently also occurs in *P. caudatum.*

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Eye Defects Associated With Glaucoma

Briggs (*Br. Jl. of Opth.* 23:469, 1934) has encountered two families in which simple glaucoma appears to be a familial condition. The mechanism by which the hereditary influence acts is unknown; defective development of the angle of the anterior chamber seems to be the most probable cause, but statistics suggest that the causes of buphthalmia, hereditary glaucoma and nonhereditary glaucoma are separate and distinct. There seems to be no association between hereditary primary glaucoma and buphthalmia. There is little evidence to support the suggestion that hereditary glaucoma is due to some degree of congenital microphthalmia with a disproportionately large lens. The first family that the author describes was probably affected through three generations, but no cases have yet been discovered in the fourth, although, curiously enough, several members of the fourth generation have defective sight. The three patients of the fourth generation who have come under observation have been found to be suffering from quite unrelated disorders of the eyes and to show no sign of glaucoma. Of eleven legitimate children of the third generation, two died in infancy; of the remaining nine, three were certainly glaucomatous and two more suffered from optic defects which were probably glaucoma; two more had defective sight which may have been due to glaucoma, and two were unaffected. One of the two unaffected members died at the age of 24, too early for the condition to be ascertained. In one member of this family a spontaneous choroidal detachment developed about three months after sclerocorneal trephining, and this persisted unchanged for a year. It was (unsuccessfully) treated by a cautery puncture and is still present. The second family comprises ten siblings, one of whom died in infancy. Of the nine living siblings, eight are said to be glaucomatous and six have been examined. Of these, five were glaucomatous and one was unaffected.—*J. A. M. A.*, Dec. 23, 1939.

CONJUGATION IN PARAMECIUM BURSARIA BETWEEN ANIMALS WITH DIVERSE NUCLEAR CONSTITUTIONS

Significance of Conjugation between Animals with Very Different Chromosome Numbers and between Animals with and without Micronuclei*

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HAVING established the existence of polyploid races in the species *Paramecium bursaria*, investigations were undertaken to determine whether the process of conjugation between individuals with very different chromosome numbers was normal, and how the chromosomes were distributed between the conjugants. Conjugation was also obtained between animals with and without micronuclei. It is the purpose of the present paper to describe in some detail the nuclear changes in conjugation between animals with very different chromosome numbers and between animals with and without micronuclei.

Material and Methods

Four races were used for the present study: *Fd*, *McD*$_3$, *Gr*14, and *S*. (For a detailed description of the nuclear conditions in these races, the localities from which these races came, and the methods of culturing these animals see Chen[2].)

Four series of slides were made:

Series I. One series of preparations of conjugating pairs (race *McD*$_3$ $\times$ race *Fd*) was made in the following manner. From a single mixture containing a very large number of animals of each race, a number of conjugating pairs were isolated and fixed every hour during the entire period of conjugation. From these preparations it was possible to ascertain the successive nuclear changes in the conjugating pairs and to determine the approximate time intervals between the different stages.

Series II. Other preparations were also made of conjugating pairs which were isolated from other mixtures of these two races (*McD*$_3$ and *Fd*) made at different dates which may be far apart. One or more sets of slides were made of the conjugants from each mixture, each set containing animals which were fixed at one time. From the same mixture a number of conjugating pairs may be fixed about six hours after onset of conjugation, another group of pairs fixed about eleven hours after onset of conjugation, etc. The time interval between the onset of conjugation and the time of fixation is known in every case.

Series III. A series of preparations of conjugating pairs (race *Gr*14 $\times$ race *S*) was made in exactly the same way as for Series I except that the conjugating pairs were fixed every two hours.

Series IV. Other preparations of conjugating pairs of these two races (*Gr*14

*Contribution from the Department of Zoology, Johns Hopkins University; the Department of Zoology, University of California at Los Angeles; and the Department of Protozoology, School of Hygiene and Public Health, Johns Hopkins University.

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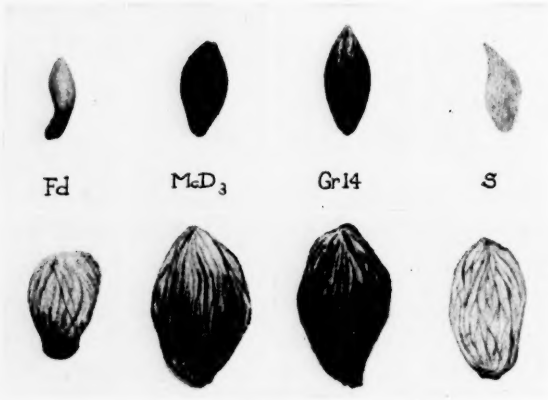


VEGETATIVE RESTING MICRONUCLEI AND PRONUCLEI IN FOUR RACES OF P. BURSARIA

Figure 9

Upper row of drawings, vegetative resting micronuclei. Lower row of drawings, pronuclei, which are found during conjugation. Nuclear membrane omitted. All figures 1640×.

× *S*) were made in the same manner described for Series II.

Schaudinn's fluid containing glacial acetic acid (95 cc. Schaudinn's fluid and 5 cc. glacial acetic acid) at 50°-60° C. was used in most cases for fixation and the animals were subsequently stained in iron haematoxylin.

It should be emphasized that for all this material *the time intervals between the onset of conjugation and the time of fixation are known.*

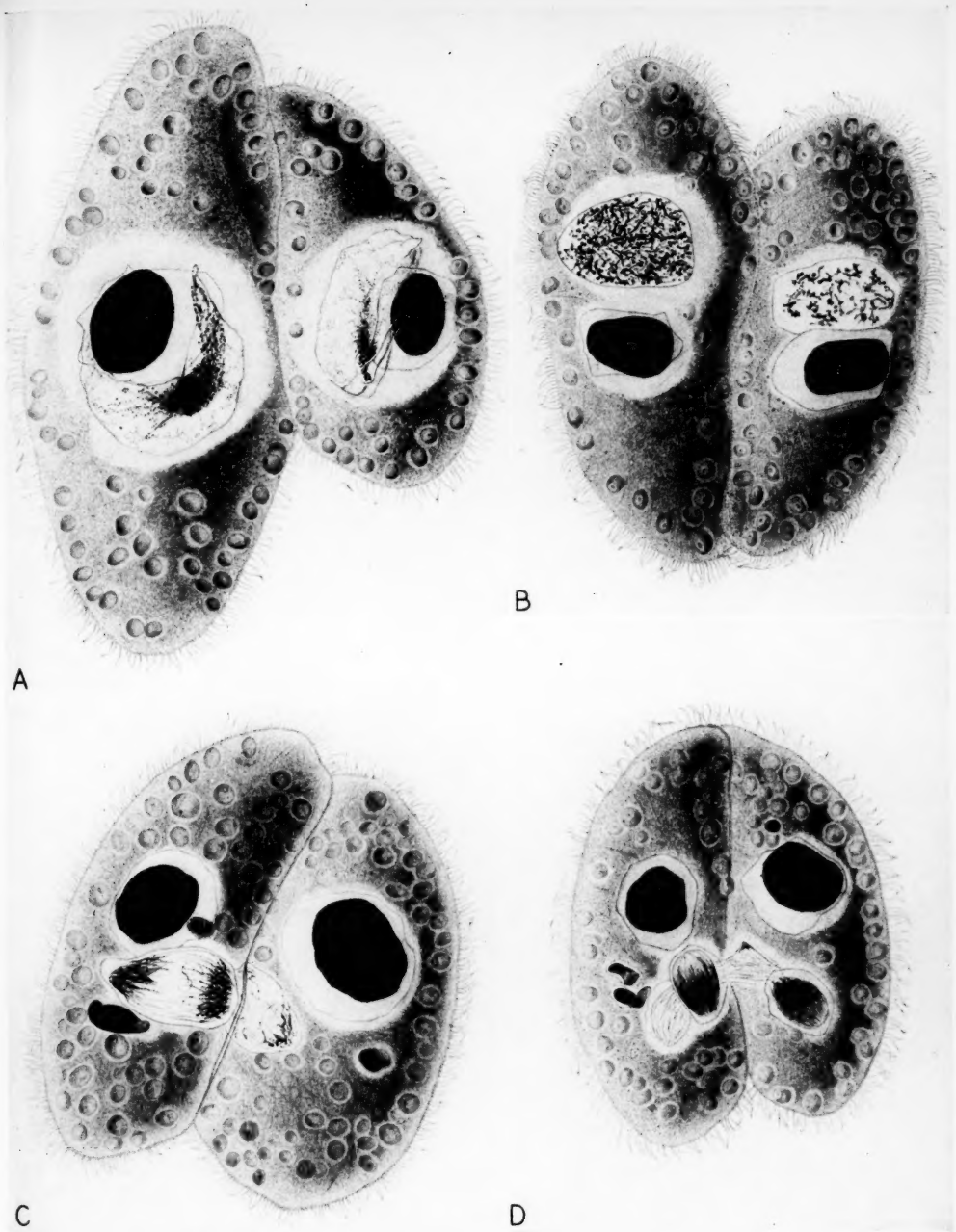
All the drawings were made with the aid of a camera lucida. The writer is indebted to Mrs. Laliah C. Runyon and Mrs. Hazel Kastner Thelen for their assistance in preparing these drawings.

The writer is also indebted to Professors H. S. Jennings, L. L. Woodruff, and Robert Hegner for critical reading of the manuscript.

Conjugation Between Animals With Very Different Chromosome Numbers

Races of *P. bursaria* with very different chromosome numbers can conjugate with each other, for example, the two races—*McD*$_3$ and *Fd,* which belong to two different mating types of Group II (Jennings[1]). The former race has several hundred chromosomes while the latter has apparently about eighty[2] (see page 182).

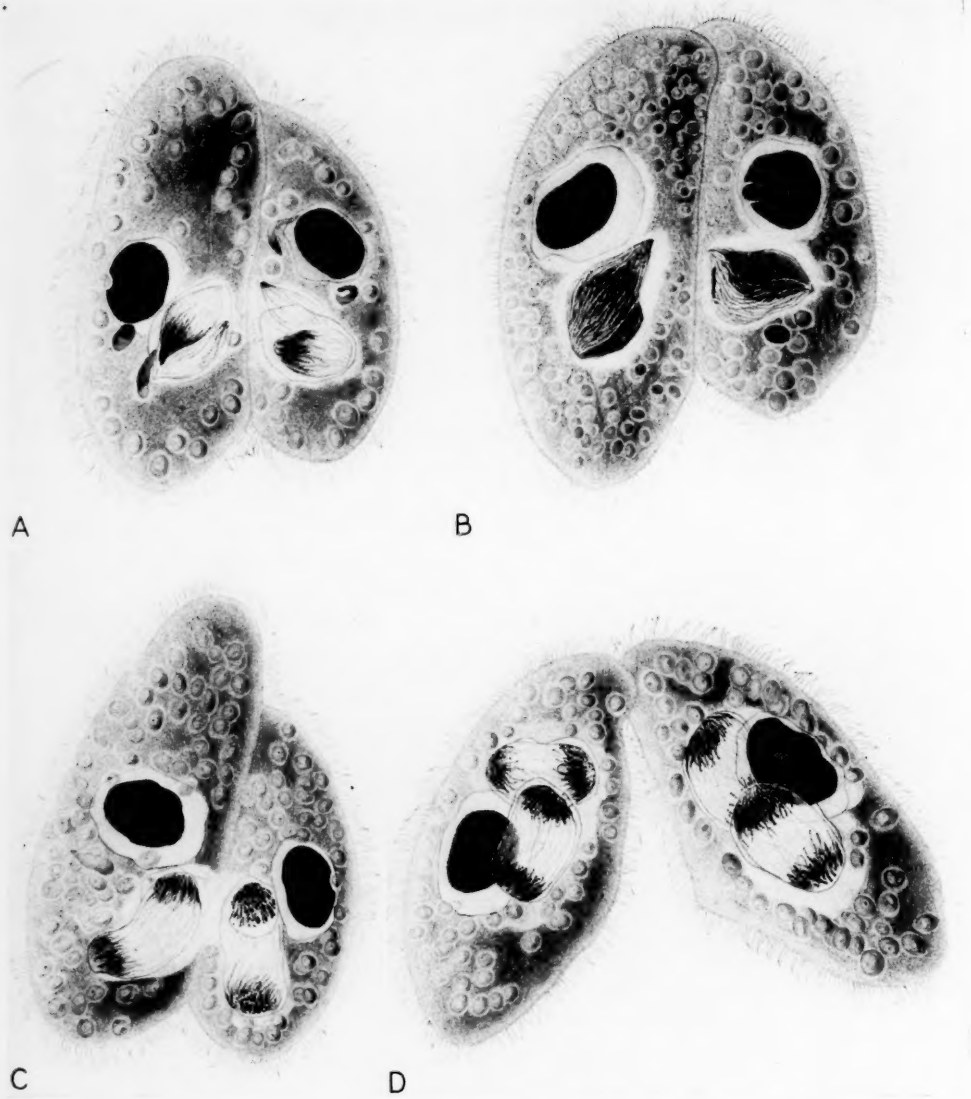
During conjugation between animals with very different chromosome numbers the nuclear changes in both conjugants are normal. The micronucleus in each conjugant undergoes three pregamic divisions. The first pregamic division is a relatively long process involving complicated prophase changes. These include gradual swelling of the micronucleus, the formation of a crescent-shaped micronucleus (Figure 10*A*), and the formation of chromosomes (Figure 10*B*). One of the two products of the first pregamic division degenerates, leaving one micronucleus which undergoes the second pregamic division. The second pregamic division requires a very short time for its completion. One of the two products of the second pregamic division degenerates, leaving one micronucleus which undergoes the third pregamic division (Figure 10*C*). This last pregamic division which also occurs rapidly gives rise to two pronuclei, one of which be-



CONJUGATION BETWEEN ANIMALS WITH VERY DIFFERENT CHROMOSOME NUMBERS

Figure 10

A—Early prophase of the first pregamic division. Crescent-shaped micronuclei. Note difference in the quantity of chromatin in the two conjugants. About 18 hours after onset of conjugation. *B*—Late prophase of the first pregamic division. Note difference in the chromosome number in the two conjugants. About 19½ hours after onset of conjugation. *C*—Anaphase of the third pregamic division. Note the difference in the size of the micronuclei and in the number of chromosomes in the two conjugants. About 26 hours after onset of conjugation. *D*—Exchange of pronuclei. The migratory pronucleus of the McD_3 conjugant (on the left) has already passed to the *Fd* conjugant. The connection between the migratory and stationary pronuclei of the *Fd* conjugant persists. About 31½ hours after onset of conjugation. All figures 820×. Cilia in all drawings diagrammatic.



LATER STAGES OF CONJUGATION BETWEEN ANIMALS WITH VERY DIFFERENT CHROMOSOME NUMBERS

Figure 11

A—After the exchange of pronuclei, each conjugant possesses one darkly stained pronucleus (from the McD_3 conjugant) and one smaller, lightly stained pronucleus (from the *Fd* conjugant). About 31½ hours after onset of conjugation. *B*—Formation of syncaryon. Note that one part of the syncaryon is lightly stained while the other is darkly stained. The lightly stained area is the *Fd* pronucleus, the darkly stained area is the McD_3 pronucleus. In the conjugant on the left the *Fd* pronucleus is on the top of the McD_3 pronucleus. About 27 hours after onset of conjugation. *C*—Anaphase of the first syncaryon division. The syncaryon of one conjugant is similar in size to that of the other conjugant, and they seem to contain the same number of chromosomes. The syncaryon in the conjugant on the right is foreshortened. About 31½ hours after onset of conjugation. *D*—Anaphase of the third division of syncaryon. The conjugants are about to separate. About 36 hours after onset of conjugation. All figures 820×. Cilia in all drawings diagrammatic.

comes migratory, the other stationary. Throughout these stages, it is clearly observed that the micronucleus in one conjugant (McD_3) is larger and contains a much greater quantity of chromatin than the micronucleus in the other conjugant (Fd). The two pronuclei in the McD_3 conjugant are also larger and stain much more deeply than those in the Fd conjugant. At room temperature exchange of pronuclei between these two races (Figure 10*D*) usually occurs 28-31 hours after the onset of conjugation. After the exchange of pronuclei each conjugant contains one large, darkly staining pronucleus and one small, lightly staining pronucleus (Figure 11*A*). These two pronuclei (different in size, staining capacity, and in quantity of chromatin) in each conjugant fuse and form a syncaryon (Figure 11*B*). The syncaryon in one conjugant appears to be the same as that of the other conjugant and they both divide three times before the conjugants separate (Figures 11*C-D*). After the first division of the syncaryon, one of the nuclei degenerates and the other divides twice, giving rise to four nuclei. The nuclei resulting from the divisions of the syncaryon are alike in both conjugants. *Thus before conjugation the two conjugants are different in the size of the micronuclei and in the number of chromosomes but after conjugation they are alike.*

Conjugation between Animals With and Without Micronuclei

Animals with and without micronuclei conjugate with each other, for example, the two races—*Gr*14 and *S*, which belong to two different mating types in Group II (Jennings[1]). Race *Gr*14 has a characteristically large, darkly staining micronucleus (Figure 9). In race *S* most of the animals do not have a micronucleus, while some have a "ghost" micronucleus which does not stain with haematoxylin (Figure 9). Conjugation is readily obtained between these two races. A *Gr*14 individual can conjugate either with an *S* individual without a micronucleus (Figure 12) or an *S* individual with a "ghost" micronucleus (Figures 14*C-D*).

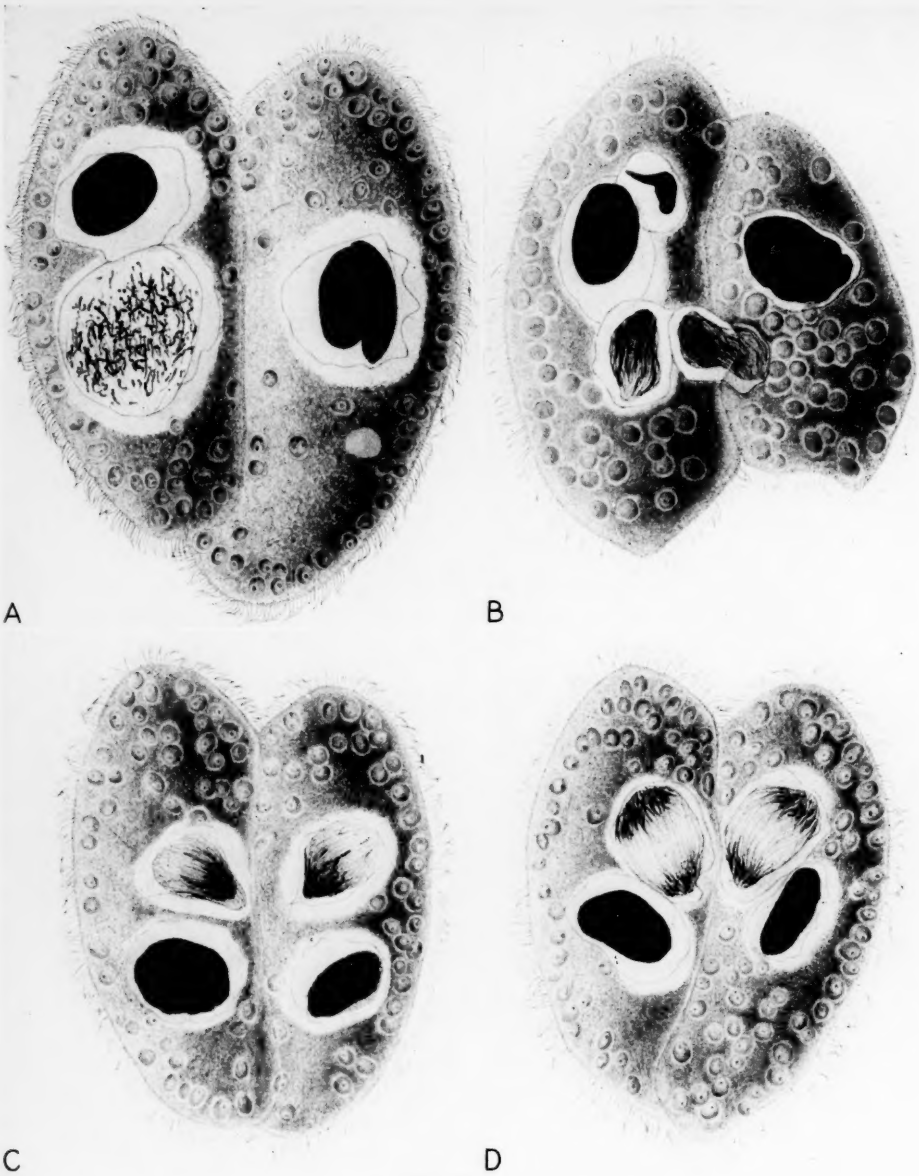
During conjugation between *Gr*14 and the amicronucleate *S*, the micronucleus in the *Gr*14 conjugant shows a normal behavior.* It undergoes three pregamic divisions (Figure 12*A*), resulting in the formation of two pronuclei. These pregamic divisions are similar to those found in conjugation between races McD_3 and *Fd*. The amicronucleate conjugant produces no pronuclei. In most of the pairs one of the two pronuclei in the *Gr*14 conjugant migrates to the amicronucleate conjugant (Figure 12*B*). After this migration each conjugant possesses a single pronucleus ("hemicaryon"†) (Figure 12*C*). Since *Gr*14 is a polyploid race, each "hemicaryon" probably still contains several sets of chromosomes. The "hemicaryon" in each conjugant behaves like a syncaryon. It undergoes three divisions before the conjugants separate (Figures 12*D*, 13*A*). After the first division, one of the nuclei degenerates, leaving one nucleus which undergoes two divisions, giving rise to four nuclei.

The nuclei resulting from these divisions of the "hemicaryon" in one conjugant appear to be the same as those of the other conjugant (Figure 13*A*) and they all seem to contain the same number of chromosomes. *Thus before conjugation the two conjugants are different in the nuclear apparatus but after conjugation they are alike.*

The account given above of the transfer of one pronucleus from the *Gr*14 conjugant to the amicronucleate conjugant

*Diller[3] mentioned conjugation in *P. aurelia* between amicronucleate and micronucleate animals but described no nuclear changes.

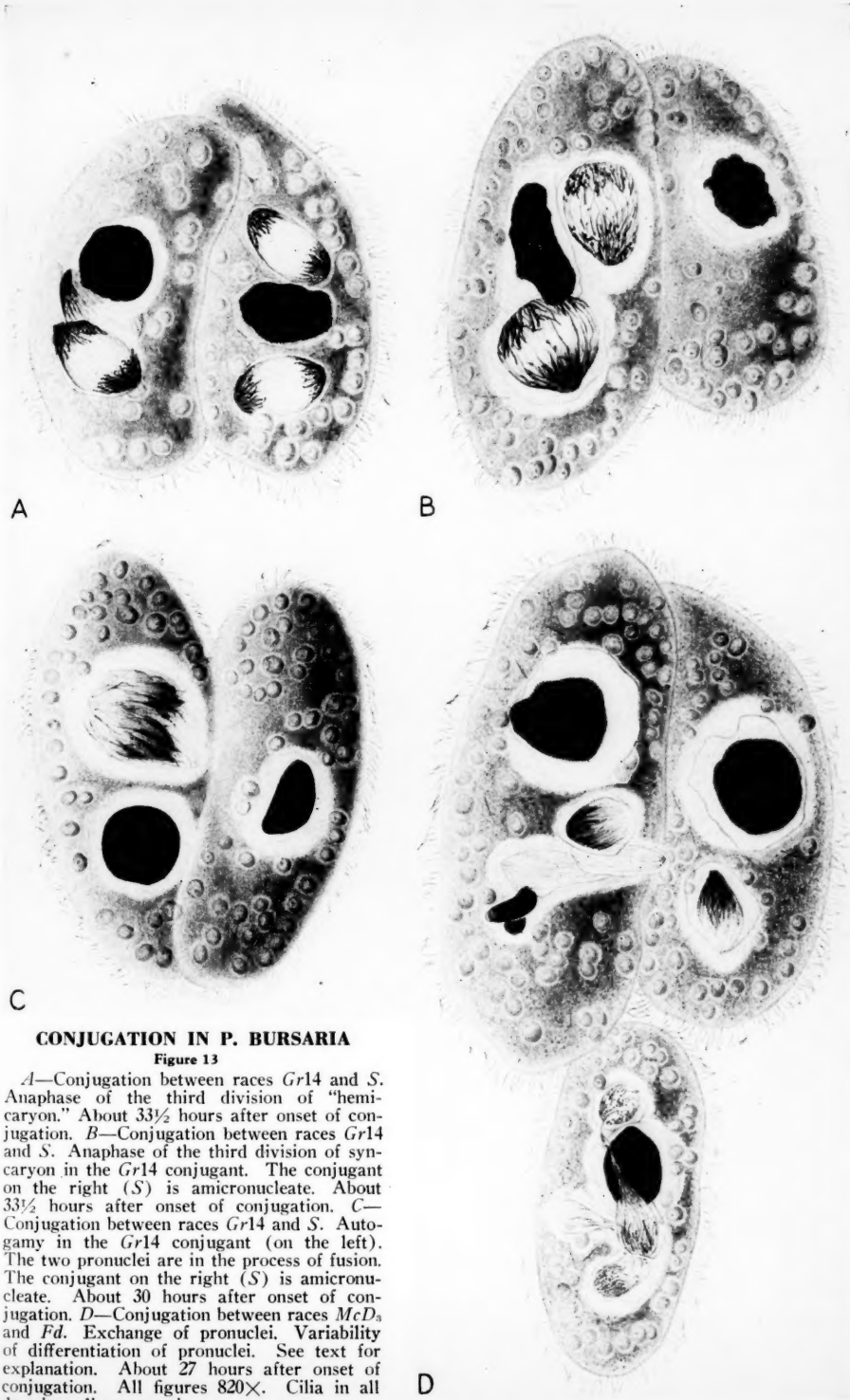
†As soon as this pronucleus in each conjugant starts to divide it should no longer be called a "pronucleus." A new term "hemicaryon" is hereby used in contradistinction to syncaryon. A syncaryon is made up of two (or more) pronuclei whereas a "hemicaryon" is composed of only one pronucleus.



CONJUGATION BETWEEN ANIMALS WITH AND WITHOUT MICRONUCLEI

Figure 12

A—Late prophase of the first pregamic division. Note the numerous chromosomes in the *Gr*14 conjugant. The conjugant on the right (*S*) is amicronucleate. About 19 hours after onset of conjugation. *B*—Transfer of one of the two pronuclei from the *Gr*14 conjugant (on the left) to the amicronucleate conjugant (*S*) on the right. Note the large and darkly stained degenerated micronucleus (probably one of the two products of the second pregamic division) in the *Gr*14 conjugant. About 27½ hours after onset of conjugation. *C*—After the transfer of the pronucleus from the *Gr*14 conjugant. Each conjugant now possesses a single pronucleus ("hemicaryon"). About 25½ hours after onset of conjugation. *D*—Anaphase of the first division of the "hemicaryon." The "hemicaryon" in one conjugant resembles that of the other conjugant, and they seem to contain the same number of chromosomes. About 27½ hours after onset of conjugation. All figures 820×. Cilia in all drawings diagrammatic.



CONJUGATION IN P. BURSARIA

Figure 13

A—Conjugation between races *Gr*14 and *S*. Anaphase of the third division of "hemicaryon." About 33½ hours after onset of conjugation. *B*—Conjugation between races *Gr*14 and *S*. Anaphase of the third division of syncaryon in the *Gr*14 conjugant. The conjugant on the right (*S*) is amicronucleate. About 33½ hours after onset of conjugation. *C*—Conjugation between races *Gr*14 and *S*. Autogamy in the *Gr*14 conjugant (on the left). The two pronuclei are in the process of fusion. The conjugant on the right (*S*) is amicronucleate. About 30 hours after onset of conjugation. *D*—Conjugation between races McD_3 and *Fd*. Exchange of pronuclei. Variability of differentiation of pronuclei. See text for explanation. About 27 hours after onset of conjugation. All figures 820×. Cilia in all drawings diagrammatic.

is true for most of the conjugating pairs. In a small number of exceptional cases, no such transfer takes places (Figures 13*B-C*). The two pronuclei in the *Gr*14 conjugant remain in the same conjugant and fuse to form a syncaryon (Figure 13*C*). A syncaryon resulting from such autogamy behaves like those formed after an exchange of pronuclei. After the first division of the syncaryon, one of the two products degenerates and the remaining nucleus divides twice (Figure 13*B*), giving rise to four nuclei. The syncaryon and its products of division are larger and contain many more chromosomes than the "hemicaryon" and its products of division (compare Figures 13*C-B* with Figures 12*C*, 13*A*). This is to be expected since the chromosome number remains the same as a result of autogamy, whereas in the case in which transfer of a pronucleus takes place the chromosome number is probably halved.

Structure of Pronuclei

The present investigation also deals with the pronuclei in *P. bursaria:* structure, differentiation, behavior, and evidences of their exchange during conjugation.

In this species the migratory pronucleus usually differs in shape from the stationary pronucleus, the former being longer and more slender, though in some cases such difference is absent. There is, however, usually no difference in size between the migratory and stationary pronuclei. (According to Calkins and Cull,[4] however, there is in *P. caudatum* difference in the size of the two pronuclei.)

As seen in the fixed and stained preparations, each pronucleus consists of (1) an enveloping nuclear membrane, (2) chromatin, the quantity and appearance of which may differ in different races, and (3) the achromatic material. The chromatin substance is generally concentrated toward one end of the pronucleus. Thus one portion of the pronucleus is darkly stained, the other lightly stained. In the exchange of migratory pronuclei it has been observed that the lightly stained region is *anterior*. An interesting feature concerning the structure and appearance of the pronuclei is the fact that they, at least in the races here reported, regularly partake of the structural pattern and appearance of the vegetative resting micronucleus (Figure 9). Among these four races, the vegetative resting micronucleus in race *Fd* is small, lightly stained, and contains a very small quantity of chromatin which is *concentrated at one end of the micronucleus.* The pronuclei in this race are also small and also show a very small quantity of chromatin which is also *concentrated at one end of the pronucleus* (Figure 9). The vegetative resting micronuclei in the races *Gr*14 and McD_3 are larger than those of race *Fd*, darkly stained, and contain a relatively large quantity of chromatin. The pronuclei in these two races are similar in these respects (Figure 9). In race *S* the animals with "ghost" micronuclei produce "ghost" pronuclei which are refractory to haematoxylin (Figure 9).

Variability in Differentiation of Pronuclei

The two pronuclei in each conjugant are usually differentiated into one migratory and one stationary pronucleus. There is, however, some variability in differentiation. The two pronuclei in one conjugant may both become migratory pronuclei and move to the other conjugant. Figure 13*D* depicts such a case in conjugation between the races McD_3 and *Fd*. Of the two anterior conjugants, the one on the left belongs to race McD_3 identified by: (1) The two large, darkly stained degenerated micronuclei. In conjugation between these two races, the degenerated micronuclei (one of the two products of the first pregamic division, and one of the two products of the second pregamic division) in the McD_3 conjugant are much larger, usually more deeply stained, and disappear much later than the degenerated micronuclei in the *Fd* conjugant. (2) The fact that the third conjugant belongs to race *Fd*. In conjugation of three animals belonging to these races, it has been found that if the third conjugant is an

Fd it is always attached to an McD_3 conjugant. In the present case, in the two anterior conjugants both pronuclei of the *Fd* conjugant have become migratory pronuclei and have almost entirely passed into the McD_3 conjugant (on the left). The migratory pronucleus of the McD_3 conjugant has entirely passed into the *Fd* conjugant (on the right).

Similar Prospective Potency of Migratory and Stationary Pronuclei

Even though the stationary and migratory pronuclei differ in shape and in behavior, they seem to have similar prospective potency. As already described, in conjugation between an animal with a micronucleus and an animal without a micronucleus, the micronucleus of the former shows a normal behavior. It undergoes three pregamic divisions giving rise to two pronuclei, the migratory and stationary. The amicronucleate conjugant produces no pronuclei. In most cases the migratory pronucleus of the micronucleate conjugate moves to the amicronucleate conjugant (Figure 12*B*). After this migration each conjugant possesses a single pronucleus ("hemicaryon") (Figure 12*C*). The "hemicaryon" in one conjugant behaves like that of the other conjugant (Figures 12 *D*, 13 *A*). It divides three times, giving rise to four nuclei which probably produce the new nuclear apparatus. Thus both the migratory and the stationary pronuclei, subsequent to differentiation, can develop independently of each other and in the same way, showing that they have similar prospective potency.

Evidence of Exchange of Pronuclei During Conjugation

Evidence of regular exchange of pronuclei during conjugation comes from: (1) conjugation between an animal with a large micronucleus and an animal with a small micronucleus, (2) conjugation between animals with and without micronuclei, (3) conjugation between an animal with a darkly stained micronucleus and an animal with a "ghost" micronucleus, (4) conjugating pairs, one member of which has three pronuclei, the other but one, (5) connecting strand between two pronuclei located in two different animals. Since the writer has already described elsewhere in the present paper (1) conjugation between an animal with a large micronucleus and an animal with a small micronucleus, and (2) conjugation between animals with and without micronuclei, a discussion of the three other sources of evidence above listed will follow.

Conjugation between an animal with a darkly staining micronucleus and an animal with a "ghost" micronucleus.

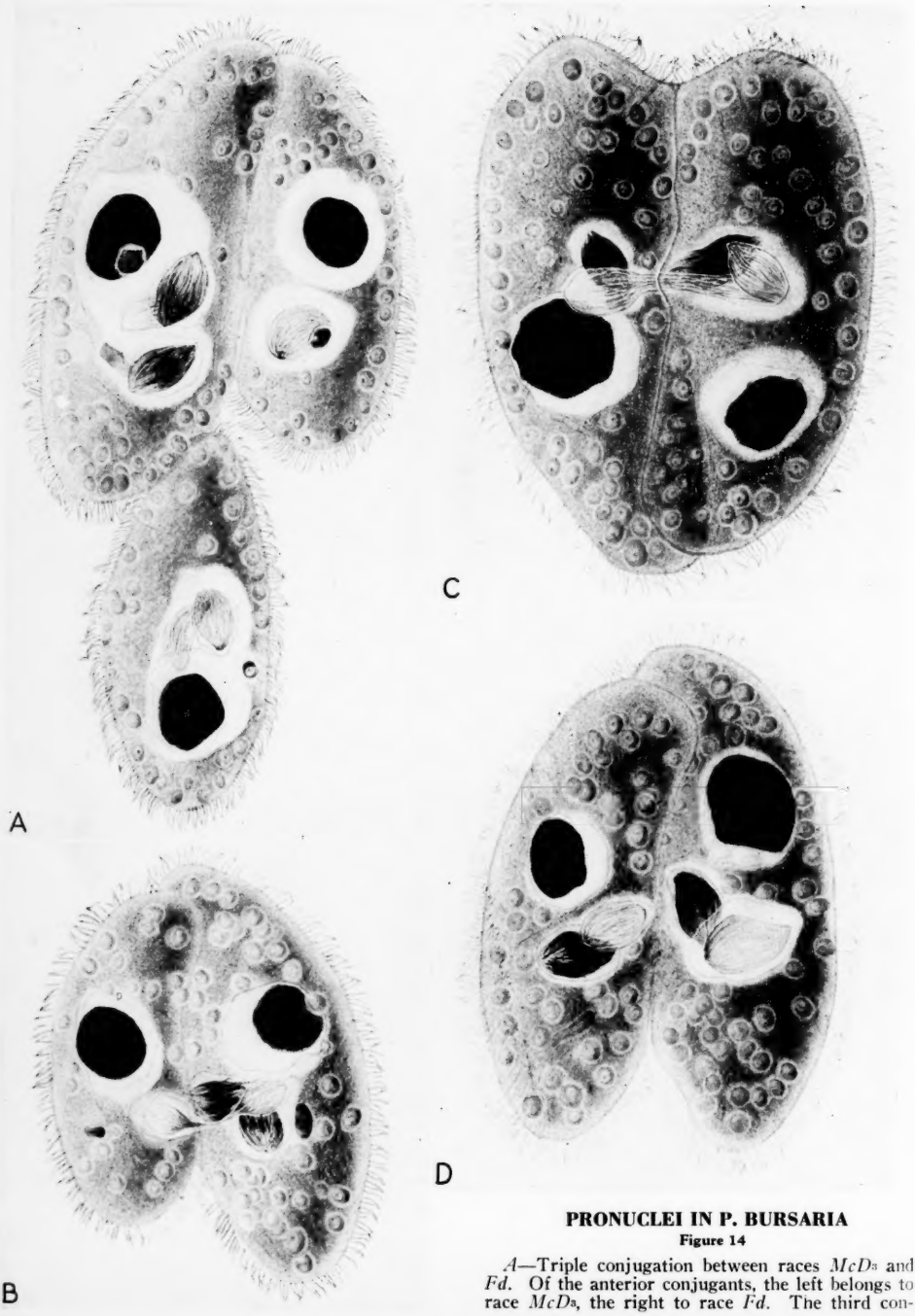
Race *Gr*14, as already described, has a characteristically large, darkly stained micronucleus. Race *S*, as already described, contains some animals with a "ghost" micronucleus and other individuals without micronuclei. In conjugation between a *Gr*14 individual and an *S* individual with a "ghost" micronucleus, the former produces two large, darkly stained pronuclei, while the latter produces two "ghost" pronuclei. In such a mating an exchange of pronuclei occurs (Figure 14*C*), after which each conjugant contains one darkly staining and one "ghost" pronucleus, respectively (Figure 14*D*).

Conjugating pairs, one member of which has three pronuclei, the other but one.

There is usually a simultaneous movement toward each other of the two migratory pronuclei in the two conjugants, but there are a few exceptional cases in which the movement is not simultaneous. One pronucleus completes its migration while the other still remains in the same conjugant (Figure 14*A*). Such a behavior gives rise to pairs in which one conjugant appears to have three pronuclei whereas the other has one, clearly indicating that an exchange of pronuclei takes place during conjugation.

Connecting strand between two pronuclei located in two different animals.

During conjugation, after the third pregamic division, at first there is a connecting strand between the two pronu-



PRONUCLEI IN P. BURSARIA

Figure 14

A—Triple conjugation between races *McD*$_3$ and *Fd*. Of the anterior conjugants, the left belongs to race *McD*$_3$, the right to race *Fd*. The third con-

clei in the same conjugant. Usually when the migratory pronucleus starts to move to the other conjugant the connecting strand has disappeared. Sometimes this connecting strand persists even after the migratory pronucleus has moved into the other conjugant (Figure 14*B*), thus clearly proving the movement of the migratory pronucleus from one conjugant to another.

Discussion

The nuclear apparatus of animals of a given species of Paramecium as found in nature is apparently usually quite uniform. Amicronucleate animals of Paramecium are rarely found in nature as are great diversities in the size of micronuclei. *Probably a very important factor in maintaining such uniformity in nuclear apparatus in nature is the elimination of diversities in nuclear apparatus and great difference in chromosome number as a result of conjugation.* Amicronucleate animals probably become micronucleate as a result of conjugation with micronucleate animals. Animals with unusually high chromosome number would have a lowered chromosome number after conjugation with animals having a low chromosome number. Animals with unusually large micronuclei would have micronuclei of reduced size after conjugation with animals having small micronuclei.

Summary and Conclusions

1. In *Paramecium bursaria,* conjugation occurs between races with very different chromosome numbers. In such conjugation the nuclear changes are normal in both conjugants. Exchange and subsequent fusion of pronuclei take place. As a result of conjugation the two conjugants possess the same number of chromosomes.

2. Conjugation occurs between animals with and without micronuclei. The micronucleus of the former shows a normal behavior, giving rise to two pronuclei, one of which migrates into the amicronucleate conjugant. Each conjugant then possesses one pronucleus ("hemicaryon") which behaves like a syncaryon in that it divides three times before the conjugants separate. As a result of conjugation, the nuclear apparatus of the two conjugants becomes alike.

3. The two pronuclei in one conjugant are usually differentiated into a migratory and a stationary pronucleus which can be recognized by their differences in behavior and in form, but the two pronuclei in one conjugant may both become migratory pronuclei. This indicates that there is variability in differentiation of pronuclei.

4. Exchange of pronuclei during conjugation regularly takes place. Evidence of such exchange comes from (1) conjugation between an animal with a large micronucleus and an animal with a small micronucleus; (2) conjugation between animals with and without micronuclei; (3) conjugation between an animal with a darkly stained micronucleus and an animal with a "ghost" micronucleus; (4) conjugating pairs, one member of which has three pronuclei, the other but one; (5) connecting strand between two pronuclei located in two different animals.

5. During conjugation between animals with and without micronuclei, the

(*Legend to Figure* 14—*continued*)

jugant also belongs to race *Fd*. In the case of the two anterior conjugants, the migratory pronucleus of the *Fd* conjugant has already passed into the McD_3 conjugant, whereas the migratory pronucleus of the McD_3 conjugant still remains in the McD_3 conjugant. About 31½ hours after onset of conjugation. *B*—Conjugation between races McD_3 and *Fd*. Exchange of pronuclei. Note the connecting strand between the migratory and stationary pronuclei (of the *Fd* conjugant) located in two different animals. The migratory pronucleus in the McD_3 conjugant (on the right) still remains in the McD_3 conjugant. About 31½ hours after onset of conjugation. *C*—Conjugation between races *Gr*14 and *S*. Exchange of pronuclei. Note the connection between the "ghost" migratory and the "ghost" stationary pronuclei. About 27 hours after onset of conjugation. *D*—Conjugation between races *Gr*14 and *S*. After exchange of pronuclei. Each conjugant possesses one darkly stained pronucleus (from the *Gr*14 conjugant) and one "ghost" pronucleus (from the *S* conjugant). The two "ghost" pronuclei appear to be unequal in size. This is an exceptional case. About 27¼ hours after onset of conjugation. All figures 820×.

amicronucleate conjugant produces no pronuclei. The migratory pronucleus of the micronucleate conjugant is usually transferred to the amicronucleate conjugant. As a result each conjugant has one pronucleus ("hemicaryon"). The "hemicaryon" in one conjugant behaves like that of the other conjugant, dividing three times, giving rise to four nuclei which probably produce the new nuclear apparatus. Thus both the migratory and the stationary pronuclei, subsequent to differentiation, can develop independently of each other and in the same way, showing that they have similar prospective potency.

The results of the present study show: (1) *There is considerable flexibility and variability in conjugation of Paramecium. Animals with a great number of chromosomes can conjugate with animals with relatively few chromosomes. Animals with micronuclei can conjugate with animals without micronuclei.* (2) *One of the results of conjugation in Paramecium is the elimination of the great diversities in the nuclear apparatus and great difference in chromosome number that may exist between the two conjugants.*

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Genetics for French-Canadian Schools

NOTING that genetics has been little taught in the French Canadian schools, particularly those of the Roman Catholic church, Dr. Rousseau (professor at the Botanical Institute of the University of Montreal) has prepared a brief manual* for private distribution to high school teachers and others. The ground covered is approximately that of a good first-year college course in genetics. In addition to the use intended, others would find it an excellent means of broadening and reviewing their French vocabulary.

Apart from its importance in agriculture, Dr. Rousseau remarks to his audience, genetics is indispensable in modern education. Knowledge of inherited defects should be widspread. Because of this, he comments that "genetics has emphasized the wisdom of certain laws of the (Roman Catholic) church concerning marriage and has demonstrated the inanity of the fundamental principle of democraries, which holds that all citizens are equal by birth. . . . It has annihilated absurdities like that of J. J. Rousseau who affirmed "that man is created good and only Society has perverted him." Thus far have the Jacques Rousseaus marched in two centuries!

Paul Popenoe.

*Rousseau, Jacques. "Cours Elémentaire de Génétique." Pp. 101. Montreal, 1938.

CYTOLOGICAL BASIS OF KILLING PLANT TUMORS BY COLCHICINE

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HAVAS,[5] following the work of Lits[6] on animal tissues and Dustin[4] on animal tumors, applied aqueous solution of colchicine in a 1:10,000 dilution to tomato plants and reported inhibition of tumor growth. The application of colchicine to the plant tumor was made indirectly by introducing it through a cut in the stem or by adding it to the soil. He suggested that inhibition of this growth was "through the intervention of the plant hormones." Brown[1] applied colchicine to a number of plant tumors directly as well as indirectly. She found that brushing half per cent to two per cent colchicine solution directly on the tumors resulted in killing them.

In studies by the senior author of polyploidy induced by colchicine,[2] the effect was found to be localized when the colchicine solution was applied directly to tissues. When tissues were subjected to prolonged treatment, cells grew to immense proportions and the primordia of stamens and other affected organs in the treated flower buds never developed normally nor reached maturity. The affected cells contained greatly enlarged nuclei, indicating that the chromosomes had doubled many times. When very young seedlings were subjected to an effective concentration of colchicine for a longer period of time than necessary to bring about only one doubling of chromosome number in the cells of the meristematic regions, they became bulbous. Such seedlings usually never developed beyond the opening of the cotyledons which were already formed in the mature seeds. These results suggested that excessive chromosome multiplication might be associated with the death of plant tumors following colchicine application.

Preliminary examination of free-hand sections of gall material on marigold (*Tagetes erecta*) produced by inoculation with *Bactrium tumefaciens* showed that in the galls treated with colchicine the actively dividing cells of the tumor had become very much enlarged and the nuclei in these cells also had increased tremendously in size as compared with control tumor material. Following these preliminary results, more detailed work was conducted. Tumors produced by inoculation of *T. patula* with *B. tumefaciens* were treated by brushing with water solutions of colchicine, varying in concentration from .01 to 1 per cent. Microscopic examination of sections of tumors was made at intervals from one day following treatment until the death of the tumor occurred.

With .01 per cent colchicine, the effect of the treatment was localized in small areas of the tumor tissue. With .025 per cent concentration the effect was more widespread through the tumor, and the increase in nuclear size in individual cells also was much greater than with the .01 per cent concentration. The increase in nuclear size reached its maximum when 0.1 per cent colchicine was used, no further increase occurring with higher concentrations up to one per cent.

In the tumors treated with colchicine solution of 0.1 per cent or higher, the increase in nuclear and cell volume was apparently continuous for about five days after one treatment. From about the sixth day after the treatment until the eighth day no further nuclear increase was apparent, but the enlargement of the affected cells continued. From about the eighth day until about the eleventh day there ensued a quiescent period when the enlargement of the affected cells also ceased. From about the

GALL DESTROYED BY COLCHICINE

Figure 15

These French marigold plants were inoculated with *Bacterium tumefaciens* 48 days before the picture was taken. When the galls resulting from this inoculation were 18 days old the one on the right was brushed once with a 2 per cent colchicine solution. The photograph was taken 30 days after this treatment. The gall at the left is the control. The insert shows the treated gall in secion.

eleventh day on, the cells of the treated tumor that had been meristematic when treated began to disintegrate, and the tumor began to shrivel and dry up.

Accurate measurements of the volume increase in the affected nuclei was impossible, but the total volume of a giant nucleus was estimated to be 512 times the normal. Based on such estimates the number of chromosomes in the giant nuclei would be 24,576 compared with the normal chromosome number of 48 for *Tagetes patula.*

Brown[1] has shown that the pathogen in some plant tumors—*Bacterium tumefaciens*—is not killed by colchicine in the concentrations used in these experiments. The bacteria, however, die consequent to the death of the galls. Since the pathogen may not be killed by the colchicine treatment, tumor growth may eventually recur. When such growth recurs in plants it can be stopped by repeating the treatment.

In actively dividing animal cells, Lits, Dustin, and others have reported that colchicine appears to have no visible effect on the cells until they reach the mitotic stage. Then all further activity is arrested, and the cells die. In plant cells, also, no visible effect appears prior to mitosis. Following mitosis, however,

MULTIPLE NUCLEI IN TUMOR TISSUE

Figure 16

Section (300×) of crown gall tissue in French marigold treated with 0.1% colchicine twelve days after inoculation. This section is from tissue fixed seven days after the colchicine application. Multiple nuclei, and enlarged single nuclei are visible in the cells.

chromosome division continues, but chromosome separation and cell division are inhibited. The mechanism of separation of split chromosomes and cell division having failed, the chromosomes, doubled in number, metamorphose into the nuclear stage and form a nucleus double in volume and in chromosome number of the original. The affected cell itself also increases in volume. Under prolonged colchicine treatment this process may be repeated until very large nuclei and cells are developed. Such cells ultimately die. The amount of chromosome multiplication that may occur without the death of the cells is not known. It may be significant, however, that in investigations to induce polyploidy usually only chromosome doubling has occurred in cells that afterward grew and divided normally.

In the control of plant tumors the colchicine application has to be made directly into or over the tumor tissue in order to effect this repeated doubling only in the tumor cells and effect the death of the tumor. When it is applied to the plant as a whole an effective dose of colchicine will cause excessive polyploidy in all regions of the plant where active cell division is occurring. It obviously will not only eliminate tumor growth, but the whole plant may succumb to it.

In much of the work with animal tumors colchicine applications have been indirect, usually by subcutaneous injection.[7] It appears obvious that by such methods there is no means of preventing colchicine from reaching and attacking normally dividing cells anywhere in the body of the tumor-bearing animal. It would seem, therefore, that the use of colchicine in the treatment of animal tumors would prove more effective if the effects of the drug could be localized.

Repeated applications of colchicine are sometimes necessary to kill plant tumors, as cells in the resting stage appear not to be affected. It may follow that in animal tumors which may be greatly reduced by colchicine treatment, repetition of the localized treatment, or colchicine in conjunction with or followed by treatments such as radiation that would affect still remaining resting tumor cells, would prove of value. Guyer has recently reported that such an effect does in fact occur, a combination of colchicine treatment and x-ray resulting in resorption of tumors in experimental cases in the rat.

A full report of the cytological studies of plant tumors treated with colchicine, with data and illustrations, will appear elsewhere.[3]

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AN EXPERIMENTAL EMBRYOLOGIST LOOKS AT GENETICS

IN the preface to his *Introduction to Modern Genetics*,* Waddington points out that in the rapid rise of what may be called classical genetics, this science "was in danger of being considered, by other biologists, as a world of its own, devoted to following the comings and goings of genes whose relevance to other biological phenomena, though incontrovertible in general theory, could rarely be stated in detail and in particular." It is especially fitting that a biologist particularly qualified in experimental embryology should set down his views on genetics because it is just this field—development—with which genetics is in need of integration. The reviewer agrees heartily with the sentiment of Waddington when he says, ". . . the different kinds of biological cobblers have in the past stuck too closely to their lasts. I want to urge that the connection between genetics and the other branches of biology, such as cytology, embryology, the study of evolution and of the biochemical nature of cell constituents, is much closer than is often admitted, and that the boundaries between these subjects deserve less attention than is usually paid to them."

Waddington's treatment is divided into five major parts: Formal Genetics, Genetics and Development, Genetics and Evolution, Genetics and Human Affairs, and the Nature of the Gene. The organization based on these divisions leads to a logical and well-expounded development of the subject. Both embryologists and geneticists will be especially interested in the author's views concerning the role of genes in developmental processes. This role, involving as it does, two intimately related and major unsolved problems of biology, the nature of gene action and the causes of differentiation, is of course far from being understood. In clearly drawing attention to and stating problems in this field, however, Waddington has stimulatingly pointed out directions in which future work may be expected to lead to significant advances.

With regard to its use as a text for students beginning the study of genetics, the book appears to the reviewer to suffer certain minor faults. The beginning section, the Fundamentals of Mendelism, including Mendel's laws, the chromosome theory, treatments of mitosis and meiosis, the relation of genes and chromosomes, independent assortment and linkage, is perhaps rather condensed, these subjects being covered in 23 pages. The idea of chromosomes being held in association by chiasmata during diplotene, diakinesis and metaphase of the first miotic division is presented early but the relation of chiasmata to terminal associations is not presented for about another 100 pages. Since terminal associations are indicated in early figures, students may suffer some confusion. Certain figures such as those involving crossing-over (e. g., 49 and 50) are rather difficult to follow. For students somewhat more advanced—and the book will perhaps be found generally more suitable for use by such students—these matters are of less consequence.

A 26-page bibliography combined with an author index is included. The subject index is well organized and adequately subdivided. There is a useful brief appendix on laboratory methods for class work on Drosophila.

On the whole the book is well and stimulatingly written with only a few errors such as inevitably creep into a first edition. It will unquestionably be welcomed as an up-to-date treatment of the subject of genetics. In addition to serving as a textbook, this volume will be found valuable as a general reference for all students of genetics, and it can be recommended whole-heartedly to professional geneticists, embryologists and other biologists.

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*WADDINGTON, C. H., *An Introduction to Modern Genetics.* 441 pp. New York: The Macmillan Co., 1939.

CONSEQUENCES OF INBREEDING IN BAJRI*

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PEARL millet (*Pennisetum typhoides*), under the local name of Bajri, is second in importance only to Juar (*Andropogon Sorghum*) as a cereal crop in the Bombay Presidency. Its agronomic value in this area is due to the fact that it is possible to mature the crop on the moisture supplied by the monsoon rains, which begin in June and furnish the major part of the annual rainfall during the following three months. The short season of millet makes it possible to mature a fair crop even in years of light rainfall. In addition to its value as a cereal the straw is an important source of fodder for cattle.

Genetic improvement of bajri had been in progress at Poona for over ten years. The work there resulted in a number of strains which were fairly well adapted to lighter soils. In heavier soils the strains proved rather early and could not compete in yield with the local varieties. The Poona work was, therefore, transferred in 1932 to the newly opened Cereal Breeding Station at Kundewadi (Niphad) in the Nasik district.

As the bajri plant is almost entirely cross-fertilized it was decided to undertake inbreeding so as to obtain material as pure as possible. These efforts have brought to light certain anomalies which are of genetical interest, and some of the most conspicuous of these are here reported. Moreover, the inbreeding project has revealed to us definite limitations of building up improved strains of this crop plant by this means.

Chlorophyll Deficiencies

As is usual with cross-pollinated crops, chlorophyll abnormalities appear in bajri when it is inbred. Ayyangar[2] and his co-workers noted albinos and pale-green plants in this millet, and reported the mode of inheritance of these deficiencies. In studying inheritance in bajri, these workers experienced great difficulties due to the protogynous nature of the crop. Our experience supports their observations. We have attempted to overcome the difficulties of controlling pollination but have failed to preclude contamination. Nevertheless, our studies have indicated a probable mode of inheritance of the various chlorophyll deficiencies.

We have not observed any deficiencies in the out-pollinated crop, but inbreeding has so far brought to light six types of chlorophyll abnormalities. These are briefly described below and the progeny behavior of the heterozygous families is indicated in Table I[s]‡

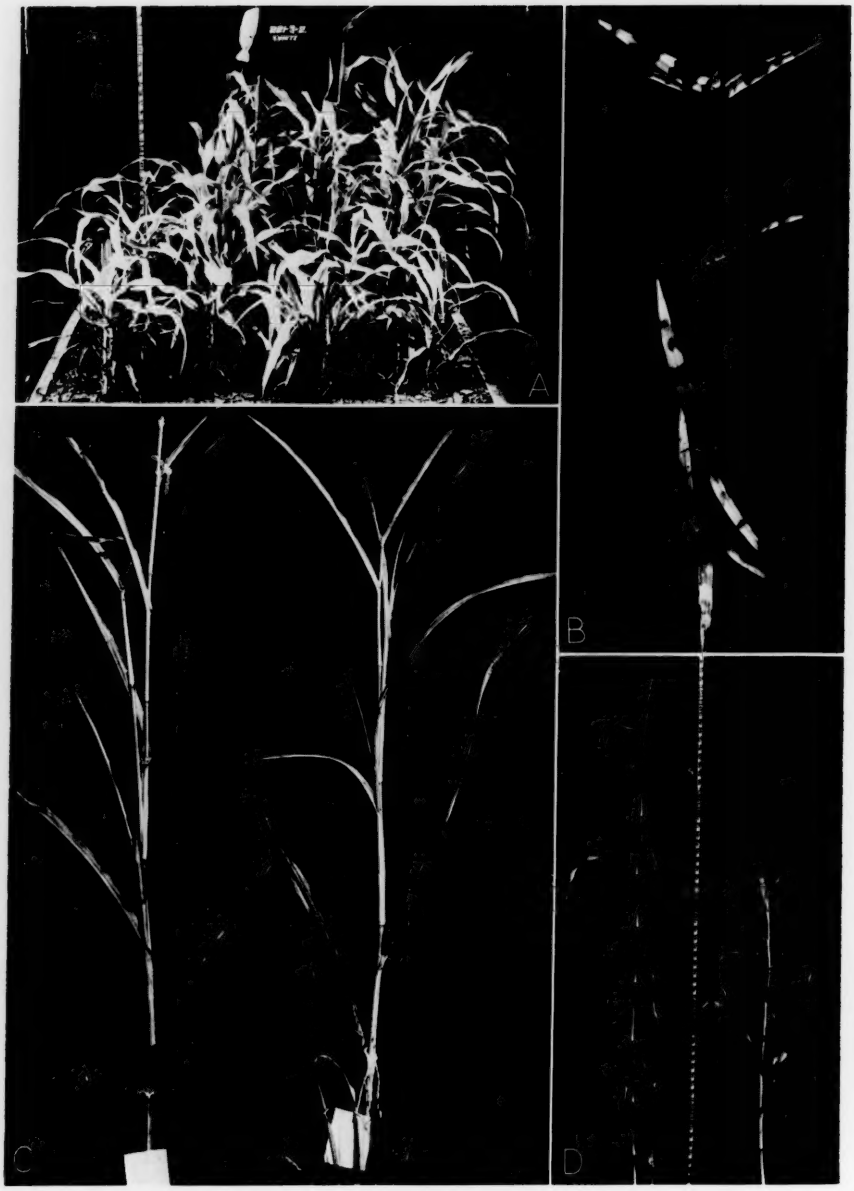
1. *Albino:* This is the most frequent type of deficiency that appears in inbred lines. The seedlings are entirely white and never develop any chlorophyll. They develop up to a two-leaf stage and perish, the period of survival being about 15 days.

Ayyangar[1] reports complex ratios and later on Ayyangar *et al*[2] mention monogenic inheritance of albinos with green as dominant. We have found wide dif-

*Contribution from the section of the Crop Botanist to Government of Bombay. Published with the approval of the Director of Agriculture, Bombay Presidency, Poona.

†Crop Botanist to Government of Bombay and Graduate Assistants respectively.

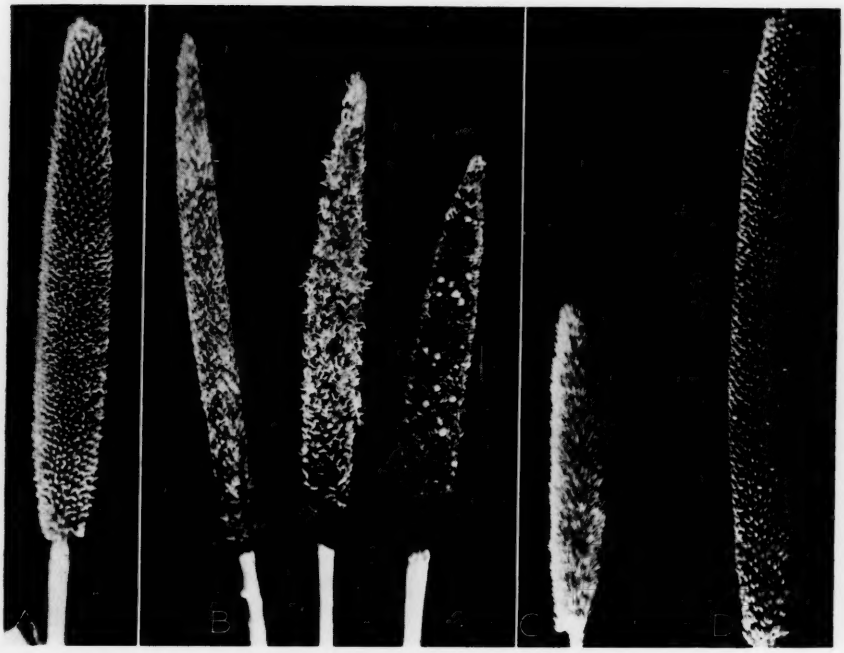
‡The four detailed tables (designated I[s] and IV[s] in the text) have been afforded supplementary publication as Document No. 1342 of the American Documentation Institute, 2101 Constitution Ave., N. W., Washington, D. C. Enclose 24 cents for the tables on microfilm, enlarged to readable size with hand-viewer, or 60 cents for photoprint, readable without mechanical aid.



CHLOROPHYLL DEFECTS

Figure 17

A—virescent white plants, a variation which is semi-lethal; *B*—shows "zebra" seedlings; *C*—"Headless" plants. Note the extremely small panicle of the left-hand plant. *D*—Normal and dwarf plants.



NORMAL AND STERILE PANICLES

Figure 18

A—normal panicle with normally developed, regularly placed stigmas; *B*—shows three stages in the development of the sterility described on page 205, showing respectively the compressed appearance of reproductive organs, anthesis and panicles characterized by abnormal anthers and stigmas; *C*—a completely sterile panicle; and *D*—a partly sterile panicle, with grains set irregularly.

ferences in segregation ratios as well as definite indications of a more complicated inheritance behavior. In Table 1[8] the first five families show segregation for green and albino plants. The first family (562 green : 84 albino) shows irregular behavior, while the next two (745 green :228 albino) show monogenic trends with some deficiency of albinos. The fourth family gives a 9 : 7 ratio of green to albino, whereas the fifth (91 green : 5 albino) shows the presence of duplicate genes, with a close approximation to a 15 : 1 ratio.

2. *Yellow:* This type of abnormality, next to albino, occurs most frequently. The seedlings emerge very light yellow, but are sufficiently colored to be immediately distinguishable in the field. Like the albinos they live only up to the two-leaf stage, and never develop any chlorophyll. Families 6 to 11, in Table I[8], show segregation of green and yellow plants. It will be seen that both mono- and digenic ratios are obtained. All the families are related; hence only two genes are most likely to be present.

In the next two families (12 and 13) we see segregation for albinos and yellows also. The frequencies indicate ratios of 12 green : 3 albino : 1 yellow.

3. *Virescent-yellow:* The first leaf emerges yellowish-white. After full emergence chlorophyll begins to develop from the base upward and within a week the leaf becomes completely green. Later on green leaves are produced and the plant resembles normal green plants. This type is of infrequent occurrence. The mortality in such plants is very

high. The survivals are weak and produce very small earheads.

In Table I[8] families from 14 to 20 show segregation for this deficiency. The first three segregate in greens and yellows and indicate duplicate and single genes. The other four families segregate for albinos also. The frequencies are rather irregular but indicate the interaction of genes for albino and virescent yellow.

4. *Virescent-white:* The first leaf is light green while the second and third are darker and remain so until they dry up. From the fourth leaf onwards all the leaves appear white. As the leaf attains full size it begins to develop chlorophyll very slowly from tip downwards and eventually becomes light green. The leaves, however, never assume the same depth of green as the normal leaves. This type also shows heavy seedling mortality. The survivals are weak and produce very small ears. The foliage intensity of the virescent white and normal green leaves may be seen in Figure 17*A*. Families from 21 to 27 show segregation of green and white virescent plants. All of them indicate a 15 : 1 ratio.

5: *Zebra:* This is a very interesting type. The first four or five leaves show alternate white and green horizontal stripes varying in number from one to three (Figure 17*B*). The white bands gradually develop chlorophyll. The development of chlorophyll proceeds from both ends of the band so that after a period oblong or round white spots result, giving the leaves a spotted appearance. Eventually these disappear as the green coloration spreads completely over the leaf. The zebra-virescent plants are weak and produce small panicles. A large number of them perish in the seedling stage.

A culture, No. 231, from the Akola bajri segregated in green and zebra virescent plants. The segregation of some families, 28 to 33, is shown in Table I[8]. Out of the six families five show segregation approximating a 15 : 1 ratio, while one family exhibits a monogenic ratio.

6. *Golden-yellow:* The first five or six leaves of this type are green in appearance and remain so until they dry up. After this stage bright-yellow leaves begin to come up and even the panicles appear conspicuously yellow. The intensity of color decreases as the plant advances in age after flowering, but compared to normal plants they are lighter in appearance. The plants of this type are more vigorous than the various types of virescent plants, but are still weaker to normal plants.

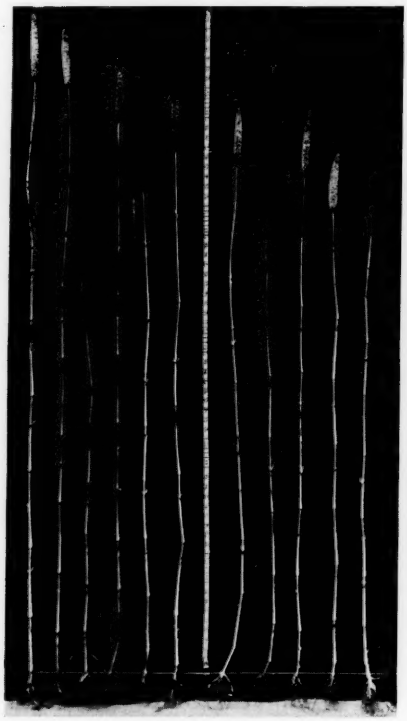
The 34th family in Table I[8] was observed to segregate for the normal and golden-yellow plants in a 3 : 1 ratio. There were 12 golden-yellow plants out of 55. The following year out of seven green plants one bred true and the rest segregated. Out of the three golden-yellow plants all tended to breed true, there being some green plants in each case due to contamination. The behavior of these families shows that the deficiency is monogenic in inheritance.

Sterility

In addition to chlorophyll deficiencies abnormalities affecting the earhead were also observed. So far four cases of sterility have been found. These are briefly described below.

1. *Complete sterility:* The earheads consist of spikelets with bristles only (Figure 18*C*). On dissection of spikelets rudimentary anthers without any pollen were found while the stigma was completely absent. During the season of 1933-34 one of the inbred lines, D-26-4-7, was observed to segregate for this form of sterility. There were ten completely sterile plants out of 123. In the succeeding season seed from 21 protected earheads was used to determine the mode of inheritance. Out of these, twelve bred pure and nine segregated. The behavior of heterozygous cultures and that of the parent line is shown in Table II[8].

It will be seen that all of the heterozygous lines show similar behavior and it appears that complete sterility is due to two duplicate genes. But in the absence of monogenic segregation of some of the



INBRED LINES
Figure 19

Each plant represents a line, all of which came from one source. Note the variation in height and earhead length, which are characteristic of the various lines.

families it is evident that the inheritance of the abnormality is complex.

2. *Partial sterility:* In this case the plants produce earheads and flower regularly. The setting of grain, however, is very irregular and in some cases no grain is set. In the flowering stage of the plant it is not possible to distinguish between the abnormal and the normal plants until after the seed is set. At this time the abnormal plants show panicles with but few grains set here and there (Figure 18*D*), while the normal plants have fully laden earheads. This type of sterility is very frequently observed.

There were three sub-families segregating for the abnormality. From each of the families three cultures were grown further. The data are summarized in Table III[s]. It will be seen that there is no indication of any definite mode of inheritance.

3. *Simultaneous appearance of anthers and stigma:* The bajri plant is protogynous. In one of the I_1 (first inbred generation) culture, AK-317, some abnormal plants were observed. As the panicle emerges both stigma and anthers are seen coming out, unlike the normal plants. The spikelets in panicles of such plants are very closely packed, the stigmas are small and the anthers look out of shape and crumpled. Most of them dry up but a few manage to produce pollen and at full anthesis dangle out. On the whole the panicle presents an abnormal appearance. Grains harvested from such abnormal plants failed to germinate. A normal earhead before anthesis and various stages of the panicles of the abnormal type are shown in Figure 18*B*.

4. *"Headless" plants:* In an inbred line, 59-I-12-1-1-3-7, peculiar plants with narrow and folded leaves were observed. Subsequently these plants were found to be with very small earheads, while the normal sibs produced fully developed panicles. On removing the flag-sheath a small stunted earhead with short peduncle was found in the abnormal plants (Figure 17*C*). The rudimentary earheads are so small that they are unable to come out of the leaf-sheath. The "headless" plants developed apical branching in greater number compared to normal plants. The apical tillers were able to put out small panicles but produced no grains probably due to the lateness of the season. There were 10 such abnormal plants out of 62.

Dwarf Plants

In the I_4 generation of a family, 28-1-8-4, a line was found with a number of dwarf plants in addition to normal sibs. The dwarf plants show shorter internodes, overlapping leaf-sheaths and somewhat shortened bent peduncles. Due to shortened peduncles the earheads remain partly inside the flag-sheath. There

were 13 dwarf plants out of 61 in the family. A comparison of the normal and dwarf sibs is shown below:

Character	Normal plants	Dwarf plants
Height in cm.*	104.40±3.55 (S.E.)	58.80±5.00
Peduncle length	26.50±1.12	10.30±1.60
Aver. number of nodes	8.48±0.04	7.84±0.25
Earhead length in cm.	15.46±0.43	13.75±0.82
Earhead thickness in cm.	2.68±0.07	1.98±0.09

*Excluding the peduncle.

It will be seen that the characters of the normal sibs are superior in size compared to the corresponding characters of the dwarf plants. In the case of height, peduncle length and earhead thickness the differences are highly significant. The physical differences of the two types of plants can be seen in Figure 17*D*.

The dwarf plants were seen only in one culture out of the eighteen lines of the family 28-1-8-4. No such plants were observed previously in any of the inbred material. It is, therefore, most likely that the dwarf plants arose as a result of gene mutation.

Differential Decline in Vigor

As in other crops the bajri plant loses vigor on inbreeding. One year's selfing is sufficient to bring down the general vigor of the plant. The first inbred generation is usually uniform, but later inbred generations show marked genetic variability. Compared to out-pollinated plants the selfed-plants are shorter in height, have less leaf area and have shorter and more slender panicles. In some, inbreeding is accompanied by a certain amount of sterility. Germination capacity in the field is also affected while in some the size of seed is also reduced.

In Table IV[8] data on differential fall in vigor of two characters, plant height and earhead length, are summarized. It will be seen from the table that there is a progressive tendency to decline in vigor. It should be pointed out that it is extremely difficult to measure the influence of inbreeding accurately, the bajri plant being extremely susceptible to environmental influences as it is dependent on monsoon rains, which are usually irregular in distribution from season to season. Thus, every year the bajri crop shows a response much different from that of the preceding year. There is, however, no doubt that progressive inbreeding tends to decrease the general vigor of the bajri plant. It will be seen also that in I_3 and I_4 generations there are clear-cut differences in height and earhead length of various cultures. The family 116-*A* is less variable than the family 207. The differences between progenies of an inbred family are illustrated in Figure 19. Each plant represents general height and earhead length of the progeny row.

Discussion

From the foregoing experimental evidence it is seen that inbreeding in bajri is accompanied by the appearance of abnormalities such as various chlorophyll deficiencies and defects of reproductive organs. In following the genic behavior of various morphological characters it was not possible in most of the cases to obtain regular or definite progeny behavior in spite of the very careful handling of the experimental material. In view of this it was suspected that contamination is taking place through the meshes of the muslin cloth employed largely for protecting panicles of bajri. Clear cut evidence on this point became available in the season of 1935 when yellowish grains were discovered among the normal bluish grains of protected panicles of the local variety. These were the results of contamination by the pollen of African bajri which has yellowish grains. Due to xenia the hybrid grains were easily detectable. That the yellowish grains, found on the protected plants of the local variety of bajri were hybrids was proved by growing them and obtaining characteristic hybrid plants in every case. Our failure, therefore, to observe regular behavior in later generations must have been largely, if not entirely, due to disabilities of controlling pollination effectively. Indeed, this appears to be the case with other workers

also, since in none of their publications do Ayyangar and his coworkers present F_3 results. The ratios indicated in Table 1[8] should, therefore, be taken as indicative and not definite. It is clear, however, that the chlorophyll deficient types are recessive. It has been possible to grow some of them pure under isolated conditions.

The effect of inbreeding of bajri is the sudden decrease of constitution in the first inbred generation. In other selfed generations differentiation begins to take place. It has been possible to build up inbred strains with varying yielding capacity. But none of these is as yet as good as the out-pollinated variety. Thus straightforward inbreeding has rather remote chances of resulting in a strain better than the local material. Other methods, such as group and community breeding are, therefore, being adopted.

Summary

1. The inbreeding of bajri (*Pennisetum typhoides*) has shown six recessive types of chlorophyll deficiencies.

2. Inbreeding has also revealed four types of recessive sterility, and a recessive dwarf type, due most probably to gene mutation.

3. Inbreeding of bajri results in greatly reduced vigor, and there is differential response in this respect.

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SWINE BREEDING IN THE CORN BELT

DEVELOPMENTS in a Regional Swine Breeding Laboratory established by the Department of Agriculture in cooperation with State Experiment Stations in the Corn Belt States were reported at a conference in Ames, Iowa, on November 10, 1939, by Dr. W. A. Craft. The cooperative laboratory was established under th authority of the Bankhead-Jones Act of 1935. The following statments are taken from the text of Dr. Craft's report.

Objectives

The primary objectives of the project are to test adequately the application of certain breeding methods for general improvement of swine and to develop measures of such characters as productiveness of sows, rate and economy of gain, general vigor, and carcass merit, which may be used effectively to supplement the methods of selection now being generally followed. * * *

It is common knowledge that the crossing of established breeds, since the breeds were formed, usually results in an increased rate of growth and general vigor. However, crossbreeding does not solve the need for further improvement of the breeds since the maintenance of purebred stock is required even for crossbreeding. We believe that further improvement of the breeds should enhance their value as pedigree stock and for crossbreeding purposes also. * * *

Results obtained during the last 25 years in corn breeding are widely known. Farmers, swine producers, and the public in general have challenged the experiment stations during the last 10 years to determine to what extent procedures which have been so effective in corn breeding are applicable to swine breeding. * * * In undertaking this swine breeding project, the directors of experiment stations, the U. S. Department of Agriculture, and the technical men identified with the project have accepted the challenge of farmers, swine producers, and the public to develop and adequately test procedures of breeding which it is hoped may aid swine producers in advancing the efficiency and quality of swine, and we invite the counsel and cooperation of all groups identified with the swine industry.***

General Procedure

How are the objectives to be accomplished? The collaborators proposed that the first procedure should be the establishment of distinct lines by inbreeding within a breed to be followed by converging the lines in single and double crosses, three-way crosses, and top crosses of boars of the different lines on random-bred sows to determine the effectiveness of inbred lines in improving such characters as those enumerated. It was believed that this

procedure was the one most likely to succeed.

In general three different intensities of inbreeding are being followed: (1) that represented by using four sires in a herd closed to outside blood, (2) that represented by the use of two sires in a herd closed to outside blood, and (3) that represented by the use of only one sire in a herd closed to outside blood. The first procedure should result in an increase of approximately 3 to 5 per cent per generation in the inbreeding, the second approximately 6 to 7 per cent, and the third about 11 to 12 per cent per generation.

One station proposed to test the effectiveness of selection when based entirely on rate of growth to 180 days of age as a means of advancing improvement in swine. Two of the stations proposed to study the results of combining two established bacon breeds into a new improved type. It is planned also to take advantage of such opportunities as may arise and circumstances permit for establishing the mode of inheritance of particular characters in the hope that cataloguing the inheritance of certain characters may be worth while.

Thus three systems of breeding are in progress at the laboratory: (1) inbreeding for the purpose of establishing inbred lines to permit converging in single and double crosses within lines and top crossing of inbred boars on non-inbred sows, (2) selection based entirely on rate of growth in a herd closed to outside blood in which the inbreeding is to be kept at a negligibly low level, and (3) selection in a herd started from crossing two established bacon breeds and subsequently closed to outside blood, selections being based on performance and carcass merit. * * *

Why a Regional Undertaking?

Experiences of directors of stations and their technical staffs from experiments in swine breeding prior to the organization of this project had demonstrated clearly that the establishment of several distinct lines of breeding within a breed was too large an undertaking for one institution. Furthermore, it was obvious that it would be at least desirable to have lines developed and tested in different States, and within different breeds to minimize error in generalizing too broadly from what might be meager data. It seemed also that scattering such experiments over a wide area should reduce the risk of losing the entire stock in the event of disaster or outbreaks of disease. Finally, concentration of swine production in the Corn Belt States, where over 60 per cent of the swine of the country are produced and over 80 per cent of the federally inspected slaughter of swine occurs, seemed to justify action on a regional basis.

The Poland China breed is being used at the Iowa, Minnesota, and Missouri stations. The Nebraska and Oklahoma stations are using the Duroc-Jersey. Hampshires are being used by the Illinois and Missouri stations; and inbred lines of Duroc-Jersey, Poland China, and Chester White are in progress at Beltsville which may contribute to the progress of the laboratory. The Minnesota station has a cross line of Landrace-Tamworth in progress at one of its substations; and the Iowa station in cooperation with J. J. Newlin, manager of Pioneer Hibred Corn Farm, Grimes, Iowa, is studying the performance of a similar cross line. * * *

What Types Should We Strive For?

If we should have only one type within the lard or bacon type breeds, it should be a general-purpose type that would best meet the needs of the producer and the preferences of the consumer. The producer desires prolific and heavy milking sows, rapid growth in pigs, maximum economy of gain, maximum resistance to disease, and flexibility in weight at finish (permitting a weight range of approximately 180 to 240 pounds without severe market penalties at either end). Consumer preferences are for maximum lean in proportion to fat, plump hams, relatively short shanks, sides with maximum uniformity in thickness, and a minimum of bone all at the lowest price possible. * * *

Results

During the two years in which the laboratory has been operating, we have had to procure and increase the stock for the establishment of inbred lines and the development of cross lines. It has been necessary also to extend the development of physical facilities at each of the cooperating stations to accommodate properly animals of the various lines and to obtain assignment of personnel for conducting the investigations. * * *

A scheme for evaluating and combining the values of different items of performance was worked out last year by Dr. Lush, project leader at the Iowa station. The scheme was derived from a collective study of data on items of performance of pigs in the laboratory project, data from pigs in record-of-performance studies which had been conducted previously at the Iowa station, and data relating to prices of different market grades of hogs. The procedure places equal value on economy of gain, merit of carcass, and individual score with rate of gain to 180 days of age having twice the value of either of the other items. Other characters such as productiveness of sows and performance of litter mates are being studied for the purpose of including these in the scheme. Careful study made of the scores during last year indicates that the scoring procedure probably has merit. * * *

A detailed study of data from the Iowa station project with respect to the influence of heredity on rate of gain in pigs was completed recently by Dr. Whatley while he was at the Iowa station. The general conclusion from the study is that weight at 180 days of age is accounted for by hereditary factors to an extent ranging between 20 and 60 per cent. * * *

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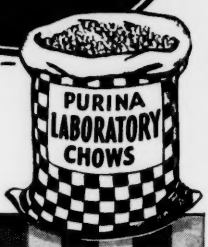

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